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ORIGINAL ARTICLES.

I.—Eminent Living Geologists:

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(WITH A PORTRAIT, PLATE XII.)

"The story of our life from year to year."

IN presenting to our readers a brief notice of the life and work of Professor Seeley, one of the most eminent of Vertebrate Palæontologists, we feel that we are offering but a scant tribute to one who has for more than thirty years occupied a leading position in the world of science. He is not only an accomplished teacher in Geology and the allied sciences in the University of London, but has long been recognized as a distinguished worker in the fields of Zoology and Comparative Anatomy. His investigations into the Fossil Reptilia of the Secondary period, and especially his remarkable researches in the Anomodont Reptilia from the Trias of South Africa, are already classic and unsurpassed. His purely geological work in the field has also made substantial contributions to our knowledge of the strata in the South of England.

In early years Harry Seeley found in the London Library and the lectures of E. W. Brayley, F.R.S., on Terrestrial Magnetism, his first introduction to Physical Geology. Lyell's "Principles of Geology" kindled an enthusiasm for observation, which afterwards secured his succession to the Chair which Charles Lyell had held in King's College as well as the Lyell Medal from the Geological Society, founded by that great master. But his scientific career appears to have been determined as a consequence of an old regulation, long since abrogated, under which he was admitted at the age of 17 as a Reader in the British Museum Library. His studies at first tended towards Anthropology, till the help of Professor Rymer Jones in Zoology, and afterwards of Dr. S. P. Woodward in Palæontology and of John Edward Gray in geographical distribution of animals, laid the foundation of a geological tendency, which was developed by the lectures of the Professors of the Royal School of Mines, and matured by field-work among the strata of the South-East of England. The personal friendship of the scientific

men of London, ever anxious to help a thoughtful student, tended to develop a broad concrete practical knowledge.

After three years of study in the galleries of the British Museum literary work took Seeley to Cambridge. Here Adam Sedgwick visited him, and invited him to become his assistant. In later years Sedgwick wrote in a printed letter—"In youth you had a reputation for genius and skill in some departments of Natural History. It was that reputation which made me seek you out and secure your co-operation as my assistant and fellow-labourer."

Seeley at once turned his attention to the local geology of the Cambridge district, and had the advantage of finding the coprolite diggings for the manufacture of superphosphate of lime, opening up an astonishing fauna in beds at the base of the Chalk, which became known as the Cambridge Greensand. He had attended Sir Richard Owen's lectures on Palæontology in London, and found this knowledge the means of dealing with the vast accumulations of vertebrate fossils which occurred in association with shells, corals, and crabs in that deposit.

His work with Sedgwick was of a kind that took the old master and the young naturalist together on many geological excursions, not only to verify new work in the local geology, but to examine the sections over again in the Isle of Wight, Isle of Sheppey, and other localities. The practical field teaching at Cambridge was soon placed in Seeley's hands, and owing to Sedgwick's illness he was called upon to lecture, often at a moment's notice, upon the subject for the day in the Professor's course. This led Mr. Seeley to prepare himself for emergencies, and to visit the important geological localities in Wales and Devon and the east and west of England, where he commonly travelled, compass in hand, sketching the physical features of the country in notebooks when the hammer was not in use.

In these days the volumes of catalogues of the Woodwardian Museum which deal with the fossil Reptilia and Ornithosauria were prepared, and printed by the University Press. For ten years his work as assistant naturalist in the Woodwardian Museum led to a series of publications in 1864 on the affinities between reptiles and birds, and to the recognition in 1869 of a bone in the British Museum which had been regarded as the tympanic bone of *Iguanodon*, as the vertebra of a new type of animal named *Ornithopsis*, the forerunner of a large order which includes the *Diplodocus* as its most conspicuous member.

About the time when the Cambridge catalogues were published in 1870, his old friend John Edward Gray invited him to enter the Zoological Department of the British Museum, and Prof. Huxley offered a recommendation for the Geological Survey. But Seeley was anxious to settle in London and avail himself of the opportunities for work in the Museums and Libraries. Some two or three years were spent in lectures and literary work. In 1876 Seeley was appointed to the Chair of Geography in King's College. His travels had enabled him to become practically acquainted with both the processes and materials used in a large number of industries, and his lectures on Economic Geography were for many years a systematic discussion of the use of

natural products by man, and of man as affected by geographical distribution. And in this work field-studies in physical geography were the basis of practical teaching, which was afterwards illustrated to his classes in the field. Some of these lectures given at the Royal Institution are printed in the first volume of Phillips's Geology, and others have been delivered at the request of the Gilchrist Trust in many towns in the British Islands. Others, again, on "Physical Geography in relation to Public Health," were communicated to the College of State Medicine.

Professor Seeley had for some time taken an active interest in the higher education of women, and in 1876 was chosen Professor of Geography and Geology in Queen's College, London,[1] and five years later succeeded to the office of Dean, on the resignation of Sir Henry Craik. Here under his teaching and guidance a large number of pupils have been trained, not only in the subjects of the curriculum, but in lectures on current topics of geological interest.

On the occasion of the Jubilee of Queen's College in 1898, on the visit of Queen Victoria, Prof. Seeley, as Dean, was presented to Her Majesty.

In 1890 he was invited to the arduous duties of Lecturer on Geology and Mineralogy in the Royal Indian Engineering College at Cooper's Hill, and in 1891 was appointed successor to Professor P. M. Duncan. Here he found an earnest body of men who soon listened to him with an affection which grew year by year, and so led them on to attain a high standard of proficiency in their work. The Indian Government supplied him with rocks, fossils, and maps from India; and geological knowledge was demonstrated in the field in short and in more extended excursions. Professor Seeley endeavoured to teach by taking his students through the methods of research, as distinct from giving them the results of research; and this may be the secret of the interest which his lectures kindled.

It was only on the retirement of the Rev. Professor Wiltshire, D.Sc., from office at King's College that the Chair of Geology and Mineralogy was conferred on Professor Seeley in 1896. At this time the teaching University was getting into work, and the subject which hitherto had been a part of the course in Engineering in King's College now became expanded to meet the wants of Civil Engineers and Mining students; while in the Faculty of Science complete courses, theoretical and practical, were arranged for the examinations of the University of London. The geological course which had been given in the Ladies' Department of King's College in Kensington Square for ten years was now relinquished. Excellent new laboratories and lecture-rooms for Geology were built in King's College, and fitted with petrological and other apparatus for a modern school of the science and for research.

During the ten years 1880–90, for which lectures were given for the London Society for the Extension of University Teaching, the most interesting result of endeavours to secure practical work as a part of the course was the establishment of the London Geological

[1] Queen's College, London, was founded with the approval of Her late Majesty Queen Victoria, who always presented a scholar to the scholarship she had founded.

Field Class. Professor Seeley has conducted excursions week by week with this Society of old pupils for twenty-one years, in the summer. It has endeavoured to provide for the whole of London a knowledge of the rocks, as the reward for each student's personal observation. Some record of the earlier teaching is preserved in the "Handbook of the London Geological Field Class," 1890. And now it has borne fruit in the recognition by the University of London of Field Teaching as a necessary condition for graduation in Geology.

Although strongly opposed in earlier years to all examinations which were not co-ordinated with teaching, he has taken part in the work of the University of London as a member of Boards of Studies in Geology, Civil Engineering, Geography, Mining, Agriculture, and Zoology, and has acted as Examiner in Geology and Zoology.

It is impossible to separate a life's work of teaching from the acquisition of new knowledge which could be imparted. Many of the British strata were followed by Seeley along their outcrops in the manner of the early masters, and enough done in the North of France, Belgium, Holland, Germany, Austria, Switzerland, and Russia to impart a distinct tone to his interpretations of many aspects of the science. An accomplished palæontologist, he has used every available museum to trace the variations in the faunas of the geological deposits as they extend through Europe, as a means of estimating their relation to the fossils of more distant regions. From about 1875, when he visited the petrological districts of the Southern Eifel, the Siebengebirge, and Eastern Rhine, and worked over the collections at Heidelberg, began the accumulation of that experience in petrology which took practical form in the new edition of Phillips's Geology, 1884, undertaken with Robert Etheridge as a personal tribute to the work of a former King's College Professor of Geology.

Studies were limited by exigencies of time. The fossil Reptiles which had led to work at Cambridge took him in after years far afield. The Pterodactyles and other types were sought out in the Highlands of Bavaria, and in the Museums of Munich, to which Zittel gave exceptional facilities, Bonn, Tübingen, Stuttgart, Bunz, and Haarlem. The Cretaceous reptiles of Gosau led to a residence for some time in Vienna, in the study of remains submitted to him by Professor Suess which were obtained in almost as complete dissociation as those of the Cambridge Greensand. He worked through all the Lias and Trias reptiles in the museums of Germany.

In 1889 Professor Seeley conceived the idea of examining the evidence of the organization of the Anomodonts. The Royal Society supported him, not only with a grant of £200 towards the expenses of travel, but by more important recommendations through departments of the Government. The results of a first visit to Russia appeared in a reconstruction of *Dinocrocodilus* and *Rhopalodon*. In the summer of the same year he visited Cape Colony, but most of the important specimens collected had already been sent to Sir Richard Owen, and it was only by traversing the colony that the geological horizons of the fossils could be determined, and new materials found. His effort was aided by the co-operation of Mr. Thomas Bain, Irrigation Officer, who was deputed by Sir Gordon Sprigg to accompany him.

Professor Seeley, in the first instance, explored the Lower Karroo rocks and found the *Parcinsaurus*, and obtained one skeleton practically complete. He then examined the Middle Karroo or Dicynodont beds, but although many interesting reptiles were found no complete skeleton of *Dicynodon* occurred. Further north, at Burghersdorp, he established a friendship with Dr. Kannemeyer, which has led to the discovery of interesting reptiles, and at Aliwal North Mr. Alfred Brown placed in his hands types, which Mr. Brown has presented to the British Museum. Near Queenstown the important skeleton of *Cynognathus* was extracted from the rock, and the skulls of *Gomphognathus* were collected. Having made a circuit of the colony after visiting Kimberley he came over the Katberg, accompanied by Dr. Atherstone, to Grahamstown, where several new reptiles awaited examination. By 1895 the more typical of these reptiles were figured in the Transactions of the Royal Society, but the materials awaiting publication are varied and not unimportant, and likely to occupy all his available leisure for some years. The described specimens have been presented to the British Museum by their discoverer, who has watched over the removal of the matrix from the bones, a task still in progress.

Professor Seeley was elected a Fellow of the Geological Society in 1862, when his godfathers were Adam Sedgwick, William Whewell, and William Hopkins. In 1872 he married Eleanora Jane, only daughter of William Mitchell, of St. George's Lodge, Bath. Mrs. Seeley has travelled with her husband in Western Europe, and assisted in the measurements of specimens in many foreign museums and in his work generally. In 1879 he was elected a Fellow of the Royal Society; in 1902 a Member Correspondant of the Imperial Academy of Sciences of St. Petersburg; and in 1905 a Fellow of King's College, London.

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1861. "Notes on Cambridge Palæontology: (1) Some new Upper Greensand Bivalves": Ann. Mag. Nat. Hist., vol. vii, pp. 116-124.

"Notices of Opinions on the Stratigraphical Position of the Red Limestone of Hunstanton": Ann. Mag. Nat. Hist., vol. vii, pp. 233-244.

"Notes on Cambridge Palæontology: (2) On some new Gasteropods from the Upper Greensand": Ann. Mag. Nat. Hist., vol. vii, pp. 281-295.

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1862. "Notes on Cambridge Geology": Ann. Mag. Nat. Hist., vol. x, pp. 97-110.

1864. "On the Fossils of the Hunstanton Red Rock": Ann. Mag. Nat. Hist., vol. xiv, pp. 276-280.

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"Cuttings from a Notebook on Chalk Gasteropods": Geologist, vol. viii. pp. 50–55, pl. viii.
"On the Hunstanton Red Rock": Quart. Journ. Geol. Soc., vol. xx. pp. 327–332; Phil. Mag., vol. xxviii. pp. 73–74.
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"On a new Lizard, with Ophidian affinities, from the Lower Chalk (*Saniwopsides dissimilis*)": Ann. Mag. Nat. Hist., vol. xvii. pp. 145–148.
"On the Literature of English Pterodactyls": Ann. Mag. Nat. Hist., vol. xv. pp. 148–153.
"On two new Pleiosaurs (*P. Hawkinsii*, *P. Willetti*) from the Lias": Ann. Mag. Nat. Hist., vol. xvi. pp. 352–360.
"On the significance of the Sequence of Rocks and Fossils": Geol. Mag., vol. ii. pp. 55, 262–265.
"On the Fossil Neck Bones of a Whale (*Palæocetus Sedgwickii* from the neighbourhood of Ely": Geol. Mag., vol. ii. pp. 54–57.
"On a Section discovering the Cretaceous Beds at Ely": Geol. Mag., vol. ii. pp. 529–534.
1863. "Notice of *Turnaceratium* and other new and little-known Fossils from the Upper Greensand or Hunstanton, commonly called the Hunstanton Red Rock": Ann. Mag. Nat. Hist., vol. xvii. pp. 173–183.
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"On the Fossils of the Carstone Formation": Ann. Mag. Nat. Hist., vol. xviii. pp. 111–112.
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1869. "Index to the Fossil Remains of Aves, Ornithosauria, and Reptilia from the Secondary System of Strata arranged in the Woodwardian Museum of the University of Cambridge": pp. xxiii, 143, 8vo, Cambridge.

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"Notes on Professor Cope's Interpretation of the Ichthyosaurian Head": Ann. Mag. Nat. Hist., vol. vii. pp. 260–268.

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"Note on some Chelonian Remains from the London Clay": Ann. Mag. Nat. Hist., vol. viii. pp. 227–233.

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1873. "On *Cryptosaurus Willetti*, Seeley, an Ichthyosaurian from the Cambridge Upper Greensand": Quart. Journ. Geol. Soc., vol. xxix. pp. 505–507.

1874. "On *Rhaptosaurus Leedsii*, a Plesiosaurian from the Oxford Clay": Quart. Journ. Geol. Soc., vol. xxx. pp. 197–208, 1 pl.

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"On Cervical and Dorsal Vertebræ of *Crocodilus cantabrigiensis* (Seeley), from the Cambridge Upper Greensand": Quart. Journ. Geol. Soc., vol. xxx. pp. 685–695.

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1875. "On the Femur of *Cryptosaurus cinereus*, Seeley, a Dinosaur from the Oxford Clay of Great Gransden": [1874] Quart. Journ. Geol. Soc., vol. xxxi. pp. 149–151.

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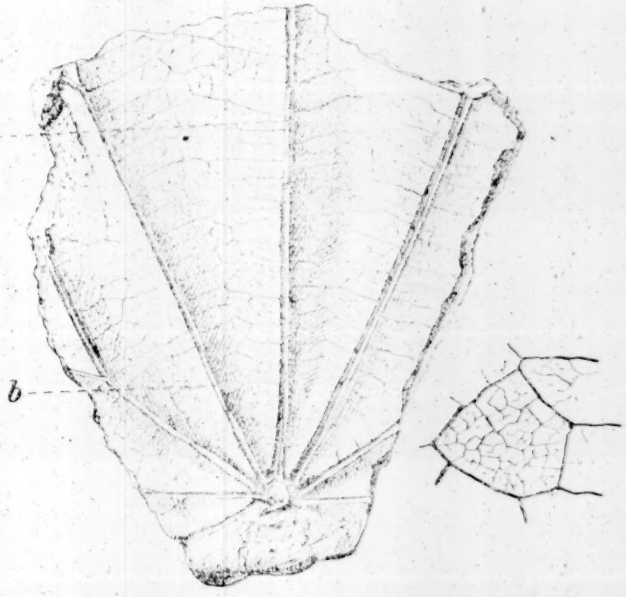
II.—Fossil Plants from Egypt.

By A. C. Seward, M.A., F.R.S., Professor of Botany, Cambridge.

THE following notes on three fossil plants handed to me by Dr. Hume have been written at the request of Capt. Lyons, Director-General of the Survey Department of Egypt. The material is unfortunately too fragmentary to admit of satisfactory determination; but in view of our ignorance in regard to the former vegetation of Egypt, it is desirable to put on record all available information. Of the three fossils only one is sufficiently well preserved to be referred with any degree of certainty to a genus.



1

Fig. 1.—*Clathropteris egyptiaca*, sp. nov.

Specimen I., Fig. 1. No. 10,714. From the sandstone (Nubian) hills east of Edfu, on the watershed between Wadi Dūm and the large valley flowing east into Wadi Abbad. Latitude approximately 25° N. Collected by Mr. H. T. Ferrar, of the Egyptian Geological Survey.

The specimen is represented natural size in the Figure; it is a portion of a fern frond with very clearly marked venation. From the base of the fragment seven strong ribs radiate through the lamina in a palmate manner; these are represented by grooves with small pieces of the axes shown at *a* and *b*. Two of the ribs are forked near the edge of the lamina. From the main veins slender branches are given off at right angles, the spaces between them being divided into polygonal areas by still smaller veins, which form a reticulum in the meshes of which the ultimate veinlets end freely. The venation is shown in the enlarged drawing to the right of Fig. 1. This type of venation is very similar to that of the recent fern *Dipteris*, which occurs in Northern India, the Malay region, and elsewhere; it characterises also certain Mesozoic genera regarded by some authors as members of the family to which *Dipteris* belongs. The Egyptian specimen clearly represents the basal portion of the lamina of a fairly large leaf, of which the main scaffolding consisted of dichotomously branched palmate ribs. A Liassic fern from Steierdorf, originally figured by Andrae as *Protorhipis Buchii*, exhibits a type of venation similar to that shown in Fig. 1. In *Protorhipis* the veins are less spreading and fork at a shorter distance from the base of the lamina; the leaf as a whole is smaller than that of which the specimen before us formed a part. The differences between the species described by Andrae[1] and the Egyptian example are clearly shown by a comparison of Fig. 1 with photographs of the Steierdorf plant published by Zeiller[2] in 1897; other species of the same genus have been figured more recently by Von Richter[3] as species of *Hausmannia* from the Lower Cretaceous of Quedlinburg.

The fragment shown in Fig. 1 should, I believe, be referred to the genus *Clathropteris*. In the fossil genera *Dictyophyllum* and *Clathropteris* the lamina is divided distally into several lobed pinnæ which are coalescent above the petiole into a continuous lamina: it is this continuous basal region which is represented in the Egyptian fragment. The two ferns *Dictyophyllum* and *Clathropteris* are no doubt very closely related, but, as Nathorst[4] says, it is probably better to retain both names on the ground that a study of a great number of forms has convinced him of the existence of well-defined differences. The specimen exhibits the rectangular venation characteristic of *Clathropteris*, but it is noticeable that in a specimen of *C. meniscoides* figured by Goeppert,[5] as in those figured by Zeiller[6] from the Rhætic of Tonkin, and by Nathorst[7] from the Rhætic of Scania, the venation

[1] Abh. k.k. Reichsanst., Bd. ii, Abt. 3, 1852.
[2] Rev. Gén. Bot., ix, 1897, pl. xxi.
[3] Beit. Flora Unt. Kreide Quedlinburg, 1906.
[4] Kungl. Svensk. Vetenskaps. Handl., Bd. xli, No. 5, 1906; also Bd., N.F. 2.
[5] Gattungen foss. Pflanzen, 1841, Lief. 5 and 6, pls. xviii, xix.
[6] Rev. Gén. Botanique, 1902.
[7] Kungl. Svensk. Vetenskaps. Handl., Bd. xli, No. 2.

in the basal part of the fronds is much less regular and less rectangular than in Fig. 1.[1] Though it is, as a rule, unwise to institute a new species on so small a fragment, I am disposed to suggest the name *C. egyptiaca* as a distinctive designation for the first example of this genus from the continent of Africa, which seems to differ from the widely distributed *C. muniscoides*, in the arrangement of the veins in the continuous part of the lamina. It is, however, possible that the specimen is specifically identical with Brongniart's species *C. muniscoides*. A short account of the geological range of *Clathropteris* and of other members of the Dipteridinæ may be found in a paper by Miss Dale and myself published in 1901.[2] The genus *Clathropteris* occurs abundantly in Rhætic rocks in many parts of the world; it is found also in strata of Liassic age. So far as it is possible to form an opinion as to the age of the rocks from a single fragment of a frond, the probability would seem to be in favour of a Rhætic age. It is, however, impossible to speak with confidence from an examination of the data at present available. Mr. Hume, of the Egyptian Geological Survey, who has read a proof of these notes, writes in a letter dated May 1st, 1907:—"*Clathropteris* was collected in such close relation to the Cretaceous (Campanian) beds that I regard the sandstone in which it was found also as Upper Cretaceous, but we are sadly in need of further evidence." There is no reason why *Clathropteris egyptiaca*, which closely resembles the recent genus *Dipteris*, should not have existed during the Cretaceous period, though such fossils as agree most nearly with the Nubian specimen have hitherto been recorded from lower horizons.

2

2*a*

Specimen II.—Figs. 2 and 2*a*. (No. 10,547.) Found on the side of a hill about 27 miles south-east of Allaqi, a station on the Nile between Aswan and Wadi Halfa; speaking roughly, latitude 22° 30′ N.

[1] Phil. Trans. Roy. Soc., 1901.

in the desert east of the Nile. Collected by Mr. P. C. A. Stewart, of the Egyptian Geological Survey.

This specimen 10 cm. in length is part of a compound frond, very imperfectly preserved: it is impossible to determine whether it is part of a bipinnate frond or a piece of a pinna belonging to a tripinnate frond.

Incomplete crowded pinnæ are given off from a rachis: these are of uniform breadth, and bear bluntly rounded pinnules 4 mm. in length, attached to the pinnæ-axes by the whole of the base. Fig. 2: enlarged rather more than four times. The specimen as a whole is practically identical in habit with a pinna of the Palæozoic species *Pecopteris arborescens*. The longest pinna is 4·5 cm. long, but when complete it must have considerably exceeded this. It is worth noting that the pinnules are inclined to the axis of the pinnæ like the arms of a wide open V, Fig. 2*a*, as in the Wealden fern *Weichselia Mantelli*.[1] It is impossible to make out the venation characters, but here and there one sees traces of a midrib and of lateral veins; in one place I noticed what appears to be a lateral connection (Fig. 2) between two of the secondary veins.

While admitting that it is futile to attempt to determine the precise nature of the fossil with any degree of certainty, I am inclined to favour the comparison with the Wealden *Weichselia* as the most likely guess at affinity.

Specimen III. Fig. 3. No. 1423. From Wadi Araba: about 300 miles north of Edfu, near the shores of the Red Sea.

The specimen consists of a few fragments of pinnæ bearing closely-set pinnules as shown in Fig. 3; the venation is more clearly seen in the enlarged drawing, Fig. 3*a*. Accurate identification is almost hopeless; it is, however, permissible to suggest that the appearance of the pinnules reminds one of a Mesozoic rather than of a Palæozoic species. Such a fern as *Alethopteris rigida* of Jurassic age presents a close resemblance in the form of the pinnæ to the Egyptian specimen.

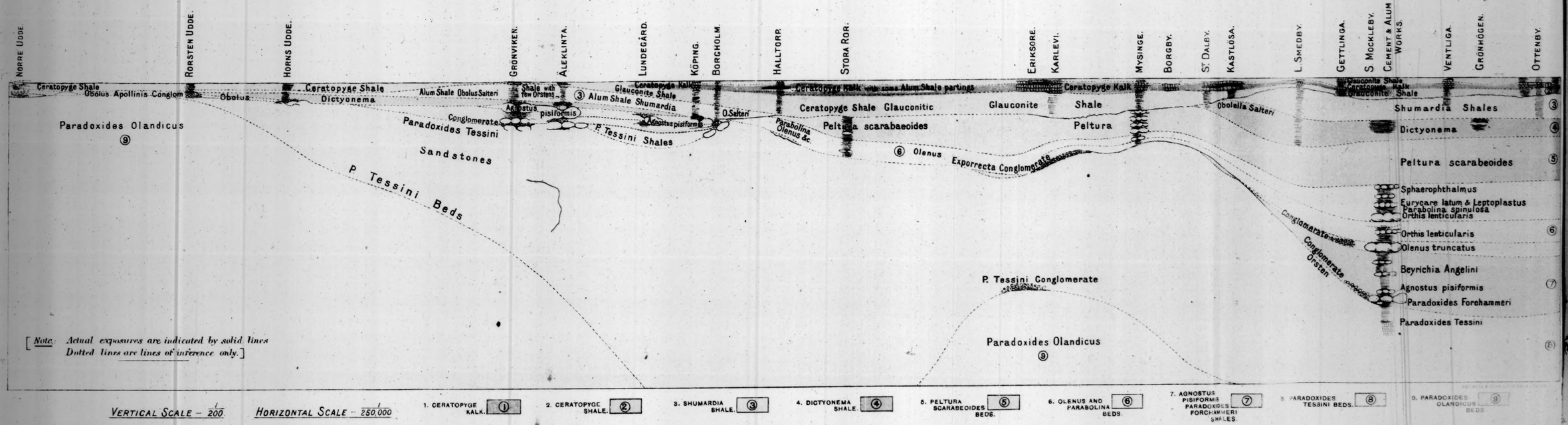
Geological Age of the Rocks from which the Specimens were obtained.

Specimen I. *Clathropteris egyptiaca*, sp. nov. Such evidence as the fragment affords is primarily in favour of a Rhætic or Lower Jurassic age.

[1] Seward: The Wealden Flora, pt. i. Brit. Mus. Catalogue, 1894. See also Nathorst: Arch. Vet. Akad. N.F. Stockh., Jahr. 14, 1890.

GENERALIZED SECTION SHOWING RELATIONS OF THE CERATOPYGE SERIES AND UNDERLYING BEDS ALONG THE WEST COAST OF THE ISLAND OF ÖLAND.

N. Geol Mag. 1907 Plate VIII. S



[Note: *Actual exposures are indicated by solid lines. Dotted lines are lines of inference only.*]

VERTICAL SCALE – 1/200. HORIZONTAL SCALE – 1/250,000

1. CERATOPYGE KALK. ①
2. CERATOPYGE SHALE. ②
3. SHUMARDIA SHALE. ③
4. DICTYONEMA SHALE ④
5. PELTURA SCARABEOIDES BEDS. ⑤
6. OLENUS AND PARABOLINA BEDS. ⑥
7. AGNOSTUS PISIFORMIS PARADOXIDES FORCHAMMERI SHALES. ⑦
8. PARADOXIDES TESSINI BEDS. ⑧
9. PARADOXIDES OLANDICUS BEDS ⑨

Specimen II. Although the state of the specimen is not such as to justify the use of a name, it is possible that it represents a fragment of *Weichselia*, and if so, the age may be put down as Wealden. This comparison is made with considerable hesitation, and it is not one to which any weight should be attached.

Specimen III. *Cladophlebis* sp. It is convenient to adopt this generic name as a designation for the pieces of pinnæ bearing pinnules of the *Cladophlebis* type.

The resemblance to *Klukia exilis*, while suggestive of a Jurassic horizon, is of practically no value, as this form of pinna is one of the commonest among ferns of different ages.

III.—The Lower Ordovician Rocks of Scandinavia, with a Comparison of British and Scandinavian Tremadoc and Arenig Rocks.

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(With a coloured Folding-Section, Plate VIII; and Plate IX.)

Introduction.

As a worker among the Lower Palæozoic rocks of Wales I have for some years devoted a good deal of time to the study of Tremadoc and Arenig rocks, and in common with others have therefore often wished to check the results attained in that district of great thicknesses and tectonic complication by reference to the thinner and more fossiliferous series of the undisturbed areas of Northern Europe. When, therefore, the Senate of the University of Cambridge granted me the Worts Fund for travelling scholars, and instructed me to study the interrelationships of the Tremadoc and Arenig Series in Scandinavia, I at once took advantage of the opportunity, and spent the months of May, June, and July in hammering over those rocks in the field.

The course of my journey took me through Skane, Öland, Dalarne, the Gefle and Upsala district, Ostergötland, Vestergötland, and the Kristiania and Eker districts of Norway in order, and with the exception of Nerike I was able to visit almost all sections where the Lower Arenig has been seen to rest upon Tremadoc rocks. The sections visited have all been described or mentioned in various local memoirs by Swedish or Norwegian geologists, but I have not been able to find any detailed English account of them, and as also I have not met with any comparative account of the variation of the various members of the succession in the different districts, I have thought that a systematic stratigraphical account of the rocks as taken from my own field observations may be of interest.

The present communication, therefore, though based entirely upon my own field notes, makes no pretence of recording new facts, and is only original in so far as it is comparative, and that its comparisons seem to bring out certain new evidence as to the physical conditions during Tremadoc and Arenig times. Except in the matter of the time variations shown by Dictyonema which is here put forward and

discussed for the first time, I have passed over all questions of palæontology and constitution of the various sub-faunas with a brief reference to the work of the Scandinavian geologists, and have quoted only such fossils as actually fell to my hammer.

In searching out the exposures discussed I have made full use of the maps and mémoirs of the Swedish Geological Survey, and in addition have enjoyed the advice of and conversation with such eminent geologists as Professors Törnquist, Brögger, Möberg, and Docents Wiman and Kjaer, to whom, as well as to other authors of maps and papers, I would tender my warmest thanks. In the course of my travels and in the working up of my field notes I have found the following papers most useful, and those who wish to pursue the subject further may be referred to them. I have arranged the references geographically in the order of the districts visited, and in the body of the paper shall refer to them by the letters and numbers appended.

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Subsequent workers will also find the recently published papers by Wiman on the Dalarne *Ceratopyge* beds (C, G.F.F., 1906, and Von Post on the similar beds of Falbygden useful, while the masterly new monograph of the "*Ceratopyge* region" by Moberg & Segerberg, Med från Lunds Geol. Fältklubb, ser. B, No. 2, 1906, like the older monograph of the graptolites of the Phyllo-Tetragraptus Skiffer by Törnquist, Lunds Univ. Arskrift (G), 1901 and 1904, is quite indispensable to all students of "Lower Silurian" palæontology. The "*Ceratopyge* region" monograph contains also a full authors' bibliography of the palæontology of the Scandinavian and some equivalent British and foreign beds here discussed, and this it is therefore unnecessary here to reproduce.[1]

Note.—The following portion of the paper in its present form was read before the Geological Society on Feb. 27th, 1907, and is published in abstract in the Proceedings of the Geological Society of March 11th, 1907.

In stating briefly the results of my work I shall consider the Tremadoc and Arenig rocks of Scandinavia in the three broad divisions—

C. *Didymograptus* shales and Orthocerakalk,
B. Glauconite shales and Ceratopygekalk,
A. *Dictyonema* and *Bryograptus* shales,

taking them in the order of their superposition. Along with division A I shall discuss also the underlying highest zone of Alum Shales (the *Acerocare* zone), into which in all parts of Scandinavia it passes continuously.

[1] See also note on this monograph in GEOLOGICAL MAGAZINE, February, 1907, by W. G. Fearnsides, p. 85.

A. *The Dictyonema and Bryograptus Shales.*

Taking first the areas where sedimentation was completely continuous throughout the period A, we may begin with the Kristiania district. Here the oldest beds in which we are interested are the upper beds of Professor Brögger's 2*d* (K 1), which both palæontologically and lithologically belong to the *Olenus* or Alum Shale Series. They contain *Parabolina heres* and *Cyclognathus micropygus*, and with them certain fragments of Asaphid trilobites, but as the Krekling section which I visited was only attainable by digging I can say little else about them. Above these come the 30 feet of shales 2*e* with *Dictyonema* and *Bryograptus*, but without trilobites, and these seem to me capable of further subdivision. Unfortunately I have no detailed knowledge of the difficult group of branching graptolites, but in the magnificent stream sections on the western side of the valley a little south of Krekling station one could easily recognize time mutations in the general aspect of the *Dictyonema* in the different beds. The earliest of them are usually ill preserved, and I could obtain no specimens showing the proximal end. In adult stipes the cells are very indistinct, and rarely project more than about a quarter of the diameter of the common canal. The connecting-rods seem to take the place of cells, and though thin are very numerous. The stipes are usually close together and very nearly parallel, they branch at all sorts of levels, and the resulting mesh has the form of somewhat elongated rectangles or parallelograms. Upwards this ancestral type of *Dictyonema* seems to diverge into two distinct families, the one approaching the true graptolites (*Dictyograptus*), while the other seems more nearly related to the Dendroids (*Dictyonema, sensu stricto*). Of these the former soon develops well-marked cells, which, though a trifle irregular, tend to become uniserial, and so come into agreement with the early graptolites, while in the latter a crinkly longitudinal ornament appears upon the polypary, and the cells though well formed are small and are developed spirally at angles of about 120°. With this divergence in the cell characters of the adult, we are able to trace an even more notable change in the character of the proximal end, for whereas the *Dictyograptids* forms develop like a fisherman's net from a sicula of no great length with primary branches diverging at an angle rarely greater than 90°, the Dictyonemas grow basket-like from a long narrow tube or nema, and diverge at angles which in the later forms approach 160°. The character of the crossbars also alters, for while in *Dictyograptus* their development is ever more and more delayed until they become practically abortive, in *Dictyonema* their importance increases, and the general aspect of the later forms is that of a square or rhomboid mesh in which crossbars and stipes are of approximately equal importance. Branching in both families appears to tend to dichotomy at regular intervals, and hence the later Dictyonemas and Dictyograptids are very flabelliform. So far as one can judge the specimens figured by Brögger as *Dictyograptus flabelliformis* come a little more than half-way up the series at Krekling. They tend rather to the *Dictyograptus* than to the *Dictyonema* family, and as shown in the original figure exhibit well-marked cells on the outer stipes of the net. The

mutation *D. norvegicus*, on the other hand, seems to be a comparatively late form, and shows nearly all the features of a well-marked Dendroid. At a horizon very near the place of *Dictyograptus flabelliformis* true graptolites without crossbars appear among the Dictyonemas, and as we pass up form an ever-increasing proportion of the graptolitic content of the shales. Curiously enough, these true graptolites, which may for the present be alluded to as *Bryograptus*, though intimately interlaminated with *Dictyonema* or *Dictyograptus*, are hardly ever seen upon the same bedding plane, and it would almost seem as if they flourished under slightly different conditions. *Dictyonema* and *Dictyograptus*, though gregarious, are also to some extent exclusive towards each other.

Above the *Dictyonema* beds are the calcareous shales and limestones with *Symphysurus incipiens*, $3a\alpha$, which, though grouped by Brögger with the Ceratopygekalk, would be included in the A beds in Sweden. They mark a vast change in the character of the sedimentation, and hence the fact that Asaphids are quite as abundant as the Olenids is not surprising. The overlying Ceratopygeskiffer $3a\beta$, which shows a temporary return towards Alum Shale conditions, contains a *Ceratopyge* fauna, but the finding at Gjeitungholmen of a slab from this division showing *Dictyonema* and *Bryograptus* on the one side and *Shumardia* on the other convinces me that it is really a passage series between A and B.

In Skåne the *Dictyograptus* beds like the *Acerocare* zone below are lithologically again a part of the Alum Shales. At Sandby (near Lund) in the western district the *Acerocare* zone is subdivided by the Swedish geologists (81 and 86) into (*c*) bed with *Parabolina heros*, (*b*) bed with *Parabolina megalops*, (*a*) bed with *Parabolina acanthura* and *A. acarne*, while at Akarpsmölla an additional higher subzone (*d*) with *Acerocare* = *Cyclognathus micropyge* is also distinguished. In the bed (*b*) I was able to obtain a few fragments of Megalaspid tails, and in certain fine-grained orstens[1] of (*c*) such occurrence is not rare. Above this *Acerocare* zone come the shales and pyritous orstens with *Dictyonema*, not over well preserved, but quite like the *Dictyonema* of the lowest $2c$ of Kristiania. This bed has the further interest that it has yielded to Moberg (83) *Lingula*, *Acrotreta*, Megalaspid fragments, and a trilobite *Hysterolenus Törnquisti*, "which is intermediate between *Ceratopyge* and *Dikelocephalus* on the one hand and *Niobe* and *Megalaspis* on the other." At Fägelsangsbacke (82), a mile nearer Lund, the section is continued, with what omission I cannot tell. There the lowest bed seen is a black Alum shale with well-preserved *Clonograptus flexilis*, etc., and fine large *Obolella Salteri*. Some seven feet above this certain much weathered shales show laminæ crowded with coarse, square-meshed, strongly-barred *Dictyonema* like *D. norvegica* (and as such identified by Moberg), alternating with ill-preserved Bryograptids. Large orstens associated with these shales

[1] The name 'orsten' is applied by the Swedes to the highly crystalline bitumen-bearing concretions which occur among the Alum Shales. These are the Stinkstein or Stinkkalk of the Germans. They have been formed not long subsequently to the time of the deposition of the shales, and often contain many beautifully preserved fossils.

appear to be unfossiliferous. Half a mile further up the same stream, however, greyer shales containing a multitude of crushed Bryograptids (*B. Kjerulfi*) alternate with thin bands of impure limestone containing *Shumardia*, and are seen to underlie the Ceratopygekalk (C).

In Eastern Skane (S 10) the *Dictyonema* beds are better exposed, and at Flagabro the gradual mutation of the *Dictyonema* type along the lines suggested at Krekling can be followed in all details. The usual *Dictyonema* in Swedish collections seems to come from Flagabro and are of the true *Dictyograptus flabelliformis* type. At Gislofshammar, south of Simrishamn, the section is mostly under the sea, but the beach material thrown up provides beautiful late Dictyonemas of a basket-work type interbedded with *Clonograptus*, in addition to all the types seen at Flagabro. At Jerrestadt I was able to find the bed with *Clonograptus flexilis*, also that with *Dictyonema norvegica*, but was most interested in finding an orsten within the *Acerocare* zone which was full of *Niobe* and, I think, *Symphysurus* also. At Andrarum (S 9) the main section stops at the *Parabolina heres* zone, but in the stream bed below the Pannhusset I had the good fortune to find a fine orsten containing an early type of *Dictyonema* together with *Hysterolenus*.

In Öland the *Dictyonema* and *Bryograptus* shale succession is much reduced, and complete only in the extreme south (O 2 and O 4). The *Acerocare* zone at the top of the Alum Shales is nowhere separated, but exposures are poor at this horizon, and there is no reason to suppose that it is absent. *Dictyonema* shales to a thickness of 7 feet are recognized along an outcrop of about 20 miles in the south of the island. The only *Dictyonema* I could find are of the *D. flabelliformis* type, but the upper beds with abundant *Obolella Salteri* contain broken stipes of true graptolites, which are probably *Clonograptus*, and pass up to about 6 feet of similar shales containing brachiopods and trilobites which continue on into the Ceratopygekalk above. North of Borgholm (O 5) *Dictyonema* occurs in certain orsten pebbles and in the soft shales which form the matrix of a curious phosphatic conglomerate which is found there. This conglomerate is very inconstant and always quite thin: it rests upon and among sundry *remanié* orsten concretions of the various zones of *Olenus* shales, and the shaly beds of its matrix pass gradually up into 3 or 4 feet of quite ordinary Alum Shales with orstens. These in their lower part contain *Obolus Salteri* and horny brachiopods, while in the upper is the *Orthis Christiani* so common in the Ceratopygekalk. Further to the north *Dictyonema* and *Obolus* shales together thin to less than 20 inches, Cherty bands with thick-walled *Obolus* then come in, and the whole passes to a nodular sandy mass quite like the *Obolus-Apollinis* conglomerate of Dalarne (D 1) and Western Russia. In this the most northern district of Öland the basal *Dictyonema* shales or conglomerate transgresses still further, and rests upon the denuded but unweathered edges of the lower *Olenus* shales and the *Paradoxides* shales and sandstone (O 6).

In Vester and Öster Götland the A beds are again incomplete, but the law of the presence or absence of the various members remains to be discovered. I find no record of the occurrence of the *Acerocare*

zone within these provinces, but a thin bed of rather barren shale just below the *Dictyonema* zone may well represent it. The *Dictyonema* zone itself also is rarely seen, but its absence is probably due rather to subsequent erosion than to failure of deposition. In Vestergötland *Dictyonema* shale is recorded by Linnarsson (W 1) at certain places around Halleberg and Hunneberg, but most unfortunately I was not able there to find it. At Kelfva, west of Mössebergs (W 4), and at Orrholmen, near Gerumsberg (W 5), in the Falbygden district, however, its lower members are preserved beneath the Ceratopygekalk. At Kleva the highest beds seen contain the largest and widest meshed *Dictyograptus* I have ever seen. An orsten among the shales containing this is described by Von Post[1] as including a bedding plane with abundant glauconite, but this I did not notice.

In the Berg or Vreta Kloster district of Östergötland (E 1) there are several fine exposures, and at Storberg not less than 13 feet of *Dictyonema*-bearing shales are seen. Here the *Acerocare* beds seem to be actually missing, and a bed of calcareous or cherty sandstone with fragments of thick-walled *Obolus* and up to a foot in thickness separates the *Dictyonema* beds from *Peltura*-bearing orsten.[2] The *Dictyonema* beds seem fairly complete, and the highest beds contain stipes of true graptolites along with *Dictyonema*. These beds are worked along with the underlying *Olenus*-shales, and contain sufficient bitumen to be quite useful for fuel.

In Nerike the *Dictyonema* beds, shales, and associated sandstones appear to be absent.

From the drift of Gefle and Upsala, Wiman (B 1) has obtained many blocks of *Obolus*-bearing sandstone comparable with the *Obolus* conglomerate of Öland. Here, however, it is truly conglomeratic, contains much glauconite and some phosphate nodules, and has a limestone matrix. With it are associated boulders of certain shales containing stipes of graptolites, *Shumardia*, and also *Hysterolenus Törnquisti* (B 2).

In the Lake Siljan district of Dalarne the *Obolus* sandstone described by Törnquist (D 1) from Vicarby and Klitterberget may probably be referred here. It is now well seen in the railway cutting half-way between Rettvig and Vicarby. There it has a thickness of from 3–7 feet, and consists of fresh chips of quartz felspar and mica with angular granite pebbles and a kaolin matrix. Its cement is calcareous, and it rests upon an irregular surface of granite, which shows contemporaneous weathering, affecting different grades of rock so differently that the depth of weathered rock varies from two inches where the rock is aplitic to as many yards in the coarse-grained granite. Of fossils *Obolus Apollinis* occurs in great multitudes, but other species are indeterminate.

A Subaqueous Unconformity.—At the close of the *Dictyonema* shale period sedimentation over the eastern portion of Scandinavia must have become discontinuous, and in certain places may at times have been replaced by erosion. Of actual uplift with its attendant

[1] G.F.F.S., November, 1906.

[2] Wiman (E 2) at Vestana describes a similar sandstone bed 2·08 m. in thickness but laminated with *Dictyonema*-bearing shales.

following of overlap and unconformity there is little evidence, but a close inspection of the phenomena presented by the beds B, Glauconite shale and Ceratopygekalk, will convince the most sceptical that none of the happenings which we generally associate with spasmodic subaqueous erosion are missing. We have noted that the upper *Dictyonema* series is complete only about Kristiania and in Skåne, and that passing thence north-eastward its thickness decreases often to zero, the highest beds being the first to go. Further, we have seen that though in North Öland and Östergötland some part of the series reappears, it is always associated with a sandy or conglomeratic phosphate bed containing fragments of all manner of older Cambrian and even Pre-Cambrian rocks, and shows therefore a passage towards the *Obolus* conglomerate facies of Dalarne and Western Russia. The manner of this change is well brought out by the section through the Cambrian and *Ceratopyge* rocks of Öland (Plate VIII) which I have plotted partly from the records contained in the new Swedish Geological Survey Memoirs of the Island of Öland (O 1–6), and partly from my own observations. This section, though fairly true to scale, has a vertical scale about 1250 times the horizontal, and it will therefore be readily understood that in the field all dips are imperceptible, and that quite the most remarkable feature of the unconformity is the thinness and extraordinary regularity of the beds affected. Most unfortunately the south end of the island of Öland just fails to contain an area of continuous deposition, but from the fact that at Ottenby, as shown by Moberg (O 4), shales above and below the surface of discontinuity contain identically the same fauna, it must follow that the time value of the discontinuity must there be reduced almost to zero.

B. *The Glauconite Shales and Ceratopygekalk.*

Returning now to areas of continuous deposition, we notice first the *Ceratopyge* shale (Brögger's $3a\,\beta$) about Kristiania. This, as already mentioned, is in its lower part an Alum shale with orstens, but upwards becomes greyer and more calcareous. Its thickness is some 16 to 20 feet. Its lowest beds with their brachiopods, *Bryograptus* and *Parabolina* have been already considered with the *Dictyonema* and *Bryograptus* shales. Its middle beds also yield *Bryograptus*, but with it abundant *Shumardia*, *Agnostus Sudenbladii*, *Ealoma*, and *Ceratopyge*, while the higher nodular shales and limestones rich in *Triarthrus Angelini* seem otherwise quite indistinguishable from the overlying Ceratopygekalk. The Ceratopygekalk $3a\,\gamma$ consists (K 2) of five or six beds of a blue-grey nodular limestone, together about 4 or 5 feet thick. It is now rather difficult to work, but I was able to prove for myself the existence of *Niobe*, *Symphysurus*, and *Megalaspis* in some beds, and of *Ceratopyge*, *Ealoma*, and *Shumardia* in others. The late Tremadoc genera (British), such as *Cheiracus*, *Dikelocephalus*, and *Holometopus* (*Ampyx*), are also recorded from this horizon, though not mentioned in the zone $3a\,\beta$ below. As compared with other Scandinavian Ceratopygekalk, $3a\,\gamma$ of Kristiania is remarkable for its small content of glauconite, which here occurs only in streaks and lines with the shale partings between the nodules of the very highest

beds. The "Korrosionsgruppar,"[1] or Erosion-pocketing, to be described later, also is not much in evidence. *3a γ* gives place upward rather abruptly to the nodular grey shales of the Phyllograptus shale *3b*.

In Skane Ceratopygekalk is very indifferently exposed, and is now known with certainty only at the mill dam close to Fagelsang (S 2 and C). There separated from baked *Phyllograptus*-bearing shales by a little sill of rotten diabase, some three or four beds of decayed and very ferruginous but once crystalline limestone alternating with shales containing sheared *Bryograptus*. Both limestone and shales contain *Ceratopyge* and *Shumardia*, and pass down into the *Bryograptus Kjerulfi* shales mentioned as containing the *Dictyonema norvegica* above. A similar limestone mentioned by Linnarsson & Holst (S 10) as occurring at Jerrestadt mill in East Skåne is no longer visible.

In all other Swedish districts the failure of the sediment supply has left the *Ceratopyge* beds more or less incomplete, and only in South Öland do we find any further certain representatives of Brögger's *3aβ* of Kristiania. It is possible that similar beds were really deposited over the greater part of Öland and Vestergötland and Östergötland, but if so must have been caught up again almost immediately, and the succeeding glauconitic division can be seen to rest variously upon *Ceratopyge* shale and *Dictyonema* shale, and upon the *Acerocare*, the *Peltura*, the *Sphærophthalmus*, and the *Orthis lenticularis* zones of the Alum Shale. In these districts glauconitic shales and Ceratopygekalk together are never more than 6 or 7 feet thick, yet have a distribution which is almost universal. Despite their thinness, their variations in lithological character are multitudinous and so complex in their details that they defy further classification. As a whole the beds are characterized by the presence of a large proportion of glauconite grains and by the strange method of bedding which has been termed "Korrosionsgruppar,"[2] or Erosion-pocketing (see Plate IX.). The matrix of the glauconite varies from shale quite comparable with the Alum Shales to a limestone of the purest whiteness, and the glauconite though sometimes absent may be present in any proportion. As a rule the lower beds are more muddy and the upper more calcareous, but either upper or lower groups may be entirely absent. Whenever the glauconite is very abundant it is usually associated with knobs or nodules of brown phosphate ranging up from the size of a pea to the size of a walnut, whose unworn surface contrasts strongly with the lustrous black or green of the grains of glauconite. Pyrites in well-formed cubes or pentagonal dodecahedra in single crystals or in shapeless lumps is also rather a feature of the bed. With the phosphate nodules, especially at the base of the series, are clay galls of older beds and angular fragments of phosphatized orsten, which in some cases retain recognizable fossils. In places where the glauconite comes to rest upon a discontinuous orsten bed the shales between the individual orstens have usually been somewhat washed away, and the interspaces filled up with angular fragments of that or any other

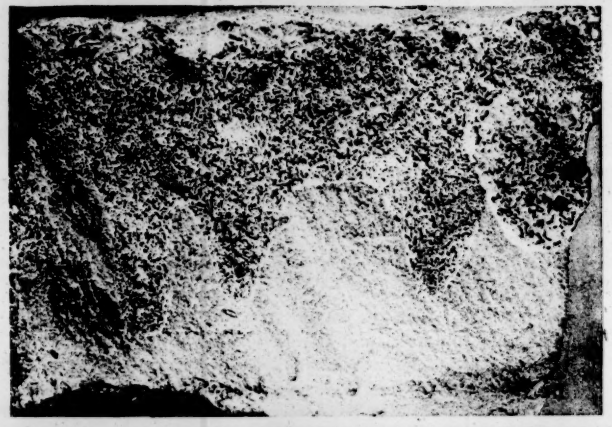
[1] J. G. Anderson, "Über cambrische und silurische phosphorit-führende Gesteine aus Schweden": Bull. Geol. Inst. Upsala, vol. iv (1899).

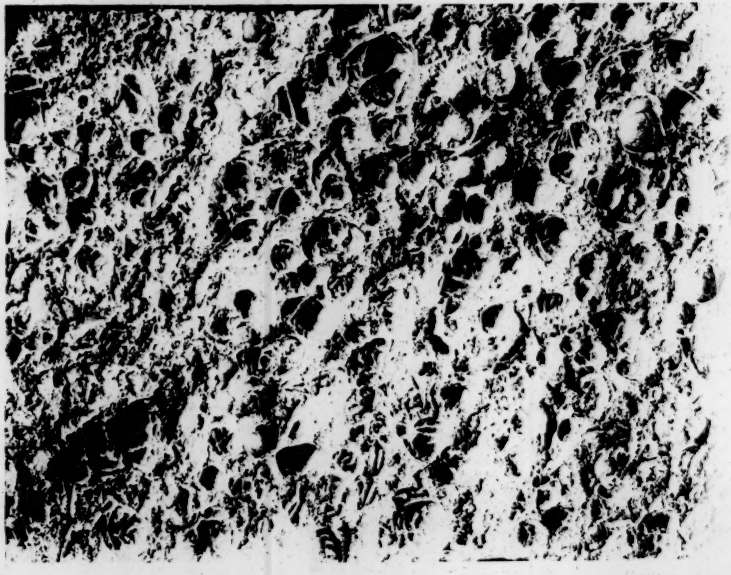
[2] J. G. Anderson: Bull. Geol. Inst. Upsala, 1899.

orsten bed with a matrix of glauconitic shale or limestone containing a *Ceratopyge* fauna. Such a phenomenon is very well seen at Nya Dala and Ekedalen in Southern Falbygden (W 5), at Mossebo under Hunneberg (W 6), and at Borgholm in Central Oland (O 5). At Dala a pair of fine flat orstens some 7 feet in diameter and crowded with *Peltura scarabæoides* were seen to overlie some 3–7 inches of glauconitic shale with *Orthis Christiani* for a length of about 6 feet. At Mossebo the upper surface of a calcareous bed with *Sphærophthalmus* is so brecciated and the basal Ceratopygekalk so dark and shaly that the line of junction is difficult to find in even the cleanest of hand-specimens. Such difficulty, however, is most unusual, and the base of the Glauconiteskiffer, however irregular, is almost always clean-cut, and the topmost Alum Shales so little weathered that either in soft shale or hard orsten the Alum Shale fossils are preserved and recognizable within a twentieth of an inch of the boundary. All these characteristics of the Glauconite shale and Ceratopygekalk it shares with most Greensand deposits, and especially with such formations as the Cambridge Greensand, which follows a period of subaqueous erosion. The phenomenon of Erosion-pocketing or Korrosionsgruppar is more peculiar, and, so far as I can learn, almost unique among known sedimentary rocks. It is undoubtedly an erosion phenomenon, and as such is difficult to describe. It has been already discussed by Anderson in his well-known monograph of the Phosphate deposits of Sweden,[1] but no English notice of it seems to have appeared, and no satisfactory explanation of its mode of formation is forthcoming.

The most striking museum specimens of Korrosionsgruppar are obtained from the base of the Glauconiteskiffer, where the rock is sufficiently calcareous to hold together, and rests upon a bed of orsten or Alum Shales also firm enough not to be friable. Such a specimen from Ulanda in Falbygden is depicted on Plate IX in Figs. 1 and 2, which show photographs of two sides of the same block taken at right angles. The figures are photographed natural size. The lower part of the block is a homogeneous, fine-grained, and somewhat earthy orsten of the *Peltura* zone, and, as is well shown by the photograph of the under-surface, Fig. 3, and by the projecting lines of trilobite fragments seen in Figs. 1 and 2, retains its bedding quite undisturbed. The junction with the glauconitic Ceratopygekalk is absolutely sharp, but quite irregular, and it may be seen that the irregularities are produced by a process of pitting rather than of grooving or moulding. The pits are generally round or oval and rather pocket-shaped, but never more than an inch or two deep, and though their mouths may vary from the size of a lead pencil to that of a five shilling piece, the diameter near the bottom is rarely bigger than a sixpence. The sides of the pits may be vertical, sometimes slightly overhanging, but they are more often inclined one towards the other downwards, and the depth is by no means proportional to the diameter of the opening. The bottom of the holes is usually somewhat rounded, and is often almost hemispherical. In general the lip of the pit is rounded, but in some cases sides of adjoining pits meet in a cusp whose solid angle may be only some 30°, but in such cases I think that the pits must be of different

[1] Bull. Geol. Inst. Upsala, 1895.





ages, and that the first one being buried in sediment the superposition of the second over a part of the site of the first must be accidental. As now observed the neighbouring pits occur so close together that over a district which, despite the ravages of denudation, still measures some 500 miles from north to south and 250 from east to west, it is rare to find a horizontal distance of more than a few inches without its pit. That at any instance during their formation the pits were so close as this is not, however, clear, and, when one considers the vast thicknesses of correspondingly coarse material which were accumulated during the period of the Glauconiteskiffer and Ceratopygekalk, is not probable. The infilling matter of the pits is almost always glauconite-bearing, and whether the matrix be soft shale or hard limestone it is noticeable that larger glauconite grains and rolled fossil fragments line the bottom, while smaller glauconite grains and matrix fill up the rest of the hollow. In this description I have hitherto only mentioned the Erosion pockets or Korrosionsgruppar, which occur at the surface of separation between the glauconite group and Alum Shales below. There the phenomenon is undoubtedly most easy to follow, but throughout the Glauconite shale and Ceratopygekalk each and every bedding plane which carries glauconites shows also Erosion pockets. The *Orthoceras* limestone also, where glauconitic, continues the same phenomenon on a more limited scale, and even where not glauconitic certain of its beds show a Korrosionsgruppar (or pocket erosion) arrangement of the coarser fragments in holes bored into more homogeneous material. Within the Ceratopygekalk bedding planes with Korrosionsgruppar occur so abundantly and near together that the successive laminæ interlock very intimately, and a considerable thickness of this slowly formed rock is rendered quite thick-bedded and massive in appearance. A freshly broken block from such a rock has the aspect of a photograph of a gravel-pit where the gravel, once calcareous, has suffered loss by solution, and has sagged down into the pipes so common under those circumstances.

EXPLANATION OF PLATES.[1]

Plate VIII.—Generalized section along the west coast of the Island of Öland, showing the actual succession and mutual relationships of the various subdivisions of the Cambrian and Tremadoc rocks there exposed. Actual observation points are indicated by solid lines.

Plate IX.—Erosion pockets or 'Korrosionsgruppar' at the base of the Tremadoc Series of Vestergotland.

Fig. 1. Northern face of a block showing the irregular boundary between calcareous glauconitic shale with *Orthis Christiani*, *Ralfsia*, *Nobi*, etc., and an even-bedded orsten of the *Peltura scarabæoides* zone.

Fig. 2. Western face of the same block showing similar phenomena. Note here the sharp cusp at the northern, right-hand end of boundary-line due to the intersection of erosion-pockets of different ages.

Fig. 3. Under-surface of same block showing good heads, etc., of *Peltura scarabæoides* undisturbed by the processes of erosion which have produced the adjoining Korrosionsgruppar.

The block, three surfaces of which are here depicted natural size, was collected at Ubuda Stenbrot, about one mile east of the church of Varnhems Kloster, Vestergotland.

[1] Plate X will appear with the conclusion of this paper in the July Number.

(*To be concluded in our next number.*)

IV.—North Norfolk Geology: The Chalk and its Dislocation.

By Sir Henry H. Howorth, K.C.I.E., F.R.S., F.G.S.

IN venturing to offer some further criticisms on the interpretation of the phenomena presented by Norfolk geology published in the memoirs of the Geological Survey and elsewhere, I may state that these criticisms are the result of several visits to the county in which I have either drawn or made detailed notes of nearly every critical section along the coast.

Another visit, in which I have recently traversed many miles of country and revisited many important sections, has greatly strengthened the views already published by me in previous papers, and has made me more than ever dubious of the greater part of the *theoretical* explanations of the local phenomena contained in these memoirs.

I have said before, and I wish now to repeat, that the frailty of much of this official work has been largely due to the fact that in East Anglia and Essex the Geological Surveyors have been so badly equipped financially by the Treasury for the work they have been expected to do, and which cannot be done efficiently until a great deal of experimental boring and other expensive modes of testing the surface beds away from the coast, below as well as on the surface, have been carried out, for which funds have not been available. To map the superficial facies of a vast area like Norfolk with no other guides to the surface beds than casual exposures in marl-pits or gravel-pits, most of which are mere shallow scrapings of the skin of the soft strata, is utterly futile, except as a tentative proceeding, and it is misleading beyond measure when, with no better guides to the distribution of these beds and of their possibly disturbed or undisturbed conditions than can be got from such accidental and adventitious exposures, far-reaching theories and explanations are published under official sanction.

This only accounts, however, for a part of the mischief. I cannot help regretting that both in regard to the accessible facts and in regard to the discussion of the theoretical inferences the memoirs in question are so inadequate. It ought not assuredly to have been left to a foreign geologist to first explain the succession of the English Chalk, including that of Norfolk, nor to two amateurs with only casual opportunities to first give a detailed and masterly zonal classification of the same beds, nor to Mr. Brydone to first give us the necessary materials for adequately discussing the problem of the Chalk bluffs at Trimingham.

Again, it is very unfortunate that in regard to the boulders of the Norfolk drift so little material should be given us in the Survey Memoirs for discriminating the original sources of the stones, the distribution and relative proportions of the different varieties in different districts, and especially the sorting out of the rolled and the unrolled boulders. It is also a pity that in analyzing problems like those connected with the drifts of Norfolk a more systematic effort should not have been made to ascertain rather more carefully from the very intelligent fishermen the nature and constituents of the

adjacent sea-bottom, and that on the other hand in dealing with the question of the origin of the local beds so much reliance should have been placed upon the foreign stones in the shingles on the shore instead of those in the deposits inland, for I am more than ever convinced that a great proportion of the foreigners in the shingles, especially the so-called Scandinavian boulders, are derived from ballast, either from wrecks or discarded from ships, and are entirely misleading in their testimony.

In regard to the *theories* which abound in the memoirs of the Geological Survey dealing with North Norfolk, and which have proved a snare to many credulous people, I hold that they are for the most part quite out of place there. Theories, especially highly polemical theories, ought to find a place in the private publications of the Geological surveyors and not in Government publications where we want facts. We can draw our own inferences.

Can anything, in fact, be more disconcerting than to find the President of the Geological Section at last year's meeting of the British Association (himself a prominent member of the staff of the Geological Survey) completely discarding the theory of interglacial periods which forms the keynote of the explanations of the Norfolk drifts in the memoirs of his own colleagues, Mr. Horace Woodward and Mr. Clement Reid, and which is adduced quite confidently as well-established in their descriptions of these beds. It is perfectly plain that if Mr. Lamplugh's address contains sound reasoning on this subject the theoretical explanation of the surface geology of East Anglia contained in the Survey Memoirs ought to be revised as soon as possible, for these theoretical conclusions are no longer tenable.

That Mr. Lamplugh is right in his views about interglacial beds I have no doubt. The only complaint I have to make is that it should be so belated. The conclusions which he now publishes as if he was the first to generalize in their sense have been pressed for thirty years in many papers and two big works by one Howorth. None of these publications are noticed in his address, which contains, by the way, a good many references to obscure foreign memoirs on the subject, which took me much time to find, and which appear in it as if they had not been previously discovered by other people. It is more to the point, however, that Mr. Lamplugh should have been constrained by the force of the evidence to discard his colleagues' views on interglacial beds so completely, and notably those of Mr. James Geikie, the author of the Glacialists' Bible.

Let us, however, proceed. I have said that until the boring rod has been used in many parts of Norfolk and Suffolk we shall never know what the true history of the later geological changes in these counties has been. The only part of the work for which adequate material is in fact available, until a great deal of such *experimental* digging has been done, is the mapping of the coast sections, which do afford exceptionally rich materials where the evidence is not hidden or distorted by the occurrence of long stretches of fallen débris forming a sloping talus. This talus, however, on a coast where the sea is very active is periodically cleared away, and fresh clean surfaces are therefore

being daily exposed, so that every part of the coast may at one time or other be critically analyzed and mapped.

The heartbreaking result of this renewal of the cliff sections, however, as Mr. Horace Woodward and others have frequently deplored, is that the constitution and the physical arrangement of the greater part of the beds in question differs so completely at different times and almost in every yard of these very famous cliffs that no section, however carefully drawn, is of more than ephemeral interest. This year's section will inevitably be of no use to us as a picture of what the kaleidoscopic beds will be like when a fresh collapse has taken place and two or three yards have been shaven off the front of the cliff. This baffling inconstancy is a continual source of complaint among all students of Norfolk geology.

It is, therefore, quite futile to generalize from any particular section without taking into account its purely transient, temporary, and local character. The kaleidoscopic feature here referred to does not apply to the whole of the sections, of course, but only to their loose materials, to the clays, loams, gravels, and sands, which everywhere overlie the more stable deposits.

I would first speak about these latter beds. From East Runton to the great shingle beds at Weybourne, where the cliffs abruptly end, the chalk, where exposed in or at the foot of the cliffs, is immediately covered by a remarkable bed, quite unmistakable, and occurring quite continuously, except in certain very limited lengths of the coast where it has been forcibly denuded. This bed does not seem to me to have been adequately described by Mr. Clement Reid. He says of it: "At Weybourne, and wherever the surface of the chalk can be examined, there is nearly always a bed of large unworn or little worn flints at the base of the Crag. This is the 'stone bed' of Norfolk geologists, but it does not necessarily belong to any one horizon; exactly similar beds of unworn flints are now being formed from above high-water mark to about 10 fathoms, and are caused merely by the wearing away of the soft chalk. The 'stone bed' is not formed by the subterranean dissolution of the chalk, for among the flints we often find bivalves in the position of life, and beneath them the chalk is here and there bored by *Pholas* and *Saxicava*."

I am bound to say I cannot think this description quite represents the facts as I have seen them in many visits. In the first place, to compare this continuous bed of flints overlying the chalk with the patches and insular areas now being formed on the foreshore occupied in some cases by an almost continuous pavement of paramoudras and in others by a similar pavement of very large unweathered and generally unbroken flints is most misleading. The greater part of the flints in the continuous beds overlying the chalk are rounded and weathered or broken, and it does not contain, except very rarely, large bizarre-shaped flints and paramoudras, but consists mainly of true rounded boulders, mostly not much larger than a cricket ball, lying, not in a kind of pavement, but heterogeneously mixed and forming a rude conglomerate, in which the contents become smaller and more rounded as we travel eastward until they become in places mere fine gravel. This bed ranges from a yard or more in thickness to

a few inches, and is bound together by oxide of iron into its normal condition of a very hard tenacious conglomerate. It seems to me that in its continuity and in its contents and structure it differs entirely from the insular and detached areas covered with unweathered flints on the foreshore with which Mr. Clement Reid compares it, and any theory based on an analogy between them must fail.

Secondly, I cannot agree with Mr. Reid that this bed "does not necessarily belong to any one horizon." In the stretch of coast I am describing it is an absolutely unique feature, which catches the eye at once, from the contrast between its dark ochreous colour compared with the white chalk below it and the grey clay or loam or sand above it, and from its running continuously along the coast separating the clays and sands above from the chalk below and forming a most unmistakable horizon. Indeed, I do not well see how such a bed could be formed at any other horizon. Its great peculiarities are the shells it contains in many places and the iron oxide which has coloured it so deeply and has indurated it into a mass of 'hard pan.' This iron oxide, it seems to me, has been added to the bed, since it lay under the sea when its shell contents were accumulated, for it could hardly have accumulated in it when it was submerged and washed continually by the sea. Its accumulation in this bed is merely due to the fact that the rain-water has percolated through the Crag and drift sands above it, whose redness and yellowness are caused by the iron oxide they contain, and that the flow of this chalybeate water has been stopped by the chalk which has filtered it and compelled it to throw down the iron oxide in the covering layer of rounded and broken flints, and has thus accumulated a very respectable mine of iron-ore in this particular bed. This condition could only happen at the top of the chalk, and it seems to me that such a bed where it exists as it does here, must mark very clearly the horizon separating the chalk from its covering beds of more or less porous sand and loam.

Thirdly, while I do not dispute the fact that this bed, before it was saturated with iron oxide, lay once at the bottom of the sea, as its contained shells clearly show, I cannot quite understand how it can have resulted from the mere submarine dissolution of the chalk, which must be a very slow process indeed, except when it is being pounded by a shingle beach and must be very largely limited to the area where these waves act and not reaching the laminarian zone. Nor can I quite understand how the rolled and broken flints in it are to be thus explained. Such beds as have clearly resulted from submarine dissolution and still remain on the foreshore have hardly any rolled or broken stones in them, but the great uncouth flints and paramoudras are held tight and do not move, and are therefore not rolled or broken except in very exceptional cases.

I believe myself that the rounded flints and occasional quartzites in this bed of hard pan (as I will call it) are in their present form much older than the shells it contains and were rolled or broken possibly in the time of the Red Crag sea or perhaps even earlier, and that the bed in question must have a very different origin from the mere submarine dissolution of the chalky matrix of the flints. This, however, is a matter which must not detain us at present.

The point I wish to insist upon is that this bed is not, as Mr. Reid argues, matched by similar beds at other horizons elsewhere, but is, on the contrary, a unique feature, and it marks most graphically for us the present upper limit of the chalk as it is seen in the cliffs and on the foreshore and marks also the base of the Crag.

This hard pan is remarkable, as I have said, for containing in many places a large number of bivalves. Quite a large proportion of these are complete valves, and a large number again have both valves united, showing they are still *in situ* in the position of life. They are jammed in among the stones, and are most clearly, as Mr. Reid says, where they actually lived. This again shows how different in essence the bed is from the insular areas of flints on the foreshore, which contain no whole shells and very few fragmentary ones.

It is perfectly plain, therefore, that since this bed was formed out of rolled materials, etc., and since it was lying at the bottom of the sea in *a quiescent condition* (otherwise the shells would have been reduced to powder), the level of the hard pan with its underlying chalk has been entirely and forcibly altered. These shells could not clearly live at a height of nine or ten or more feet above high-water mark as they now occur in many places in the cliff, but must have lived below low-water mark where the so-called laminarian zone of marine life is now found. The beds have clearly been thus dislocated in the latest geological period.

In more than one paper on the recent dislocation of the chalk in the Eastern Counties published in the Geological Magazine I have, in fact, pointed out how recent and how very potent this dislocation of the chalk has been. No evidence of the fact could be plainer than that to which I am now drawing attention. For a long distance from the cliff end at Weybourne, as far indeed as near Sheringham, the hard pan and chalk are now several feet above high-water mark. East of Sheringham the chalk with its covering, after sinking for a short distance, is again raised several feet above high-water mark. It then sinks down again to the level of the shingle, and can be traced along the foot of the cliffs to beyond West Runton. This level of the shingle, again, is several feet above the level of the laminarian zone, so it is quite plain that from the end of the cliff at Weybourne at least to West Runton the chalk and its covering have been raised many feet, or rather yards, since the shells contained in the hard pan were living, which means since the greatest part of the living mollusca existed in the adjoining sea.

This, again, is quite plain from the outline and structure of the chalk beds below the hard pan. Their surfaces are in places meandering and not level, and in places they are arched up, as shown by the curved lines of the flints in the chalk, and as figured by Mr. Reid in his memoir. At intervals, where gaps occur in the cliffs, and their surface sinks down to that of the shingle beach, the chalk for a while disappears, as at Weybourne Mill, Hithe, etc. In these cases the chalk has either disappeared through a fold forming a synclinal dip, or from some disconnection and complete breach of a more violent kind. Apart from this the level of the chalk gradually sinks to a lower point as we move eastwards. East and west of Sheringham its

surface is very irregular and broken. This is immediately before it disappears entirely from the cliff, and where it is found only on the shore at its foot.

The same irregularity in the surface contour of the chalk and the same broken and dislocated character of the same bed is found in the inland parts of the county, as has been shown by earlier writers whose observations I have collected in a previous memoir.

This last conclusion is attested by the various borings for wells which have been sunk in Norfolk, and by the exposures of chalk in chalk and marl pits. They show conclusively that the level at which chalk is reached in sinking varies very greatly, and varies in areas near one another, showing that it has been greatly disturbed and broken over a wide extent since it was deposited. Of this variation in depth at which the chalk is found in the county the Survey Memoirs afford ample evidence. The same conclusion is forthcoming again from the considerable number of great angular masses of detached chalk occurring among the drifts in various parts of the county, which in places are big enough to have permitted of chalk being quarried out of them; phenomena which have been noted by many observers, and the impressions to be drawn from which have been enlarged upon in my previous papers on the dislocation of the chalk in the Eastern Counties already referred to. In the country round Cromer and Sheringham I have lately again visited several of these pits. There is a fine one behind the mill at Weybourne; another near the road in a cutting through the hill between Weybourne and Salthouse; another behind the hill east of Beeston Hill; another near the upper gate of Mr. Upcher's park on the Holt road; a small one east of Cley, on the road to Sand; and more than one at Northrepps. In all these cases the irregularity of level at which the chalk occurs is remarkable. It is not easy to determine in many cases whether the chalk exists in a detached mass or forms the nucleus of the hill in which it is found, and has been merely raised up, but in either case the proof of some violent action is patent.

The occurrence of great masses of shelly Crag at Norwich, far from the sea and overlying the Chalk, and of other portions also at a considerable elevation in the Bure valley, shows even more forcibly how great has been the elevation and disturbance of the chalk in these latitudes since the Norwich or Weybourne Crag was deposited.

The same conclusion follows inevitably from the conditions under which the vast cakes and huge angular masses of chalk occur in the drifts at Beeston, West Runton, and elsewhere, a phenomenon which has attracted the attention of geologists for a long time and been the cause of endless discussion. From Weybourne to near Sheringham nothing is more remarkable in the cliffs than the scarcity of large flints or of masses of chalk in the clays and sands overlying the hard pan. So scarce are they that they may virtually be said not to exist at all except occasionally in the gravel sometimes capping the cliffs, and which is sometimes contained in pockets, more or less great, in hollows formed on the upper surface of the sands.

East of Sheringham the whole condition of things is changed, and thence to Cromer the cliffs are marked in several places, as the cliff

sections displayed in the Survey Memoirs show, by the vast long cakes of chalk containing flints, which have been ridiculously called chalk boulders, and which, as I have said, have been the puzzle of every inquirer, and the cause of many fantastic theories on the part of those who dislike induction but love paradox and sensation in science.

In the sections illustrating the geology of Cromer cliffs attached to the memoir on the geology of Cromer, these long cakes of chalk between East and West Runton gap are duly represented, although on much too small a scale to show their real features. In the stretch of cliff between West Runton and the brickyard in Beeston cliff there is a particularly interesting and notable enclosure in the drift which is not noticed in the sections in question, nor, so far as I know, in the literature on the subject. It may be that it has only recently been exposed in the cliff, but this seems very improbable. Like the tabular cakes of chalk just mentioned, this included mass is also remarkable for its great length and small thickness, but what makes it much more notable is the disintegrated materials out of which it is composed. When I first saw it I was particularly puzzled, because I could see from the foot of the cliff only a long serpentinous line of chalk (true chalk and not made up) curved into a sinuous shape, and extending for a great many yards, nowhere apparently more than a foot thick and thinning down to 4 or 5 inches. On climbing up the cliff I found that this enigmatical ribbon of chalk was covered with a stratum of hard pan formed of small flint pebbles and full of Weybourne Crag shell fragments, and over this again was a stratified bed of sandy and gravelly Crag, the whole united together and forming a continuous series of beds. The entire mass is more or less lenticular in shape in its thickest part, but stretches out on either side into a kind of ribbon and has been detached and transported *en masse*. Although the pebbles of flint are indurated by iron oxide, they are much more loose than elsewhere where the iron pan occurs at the foot of the cliff. There cannot be any doubt that we here have a case of a surface layer or rather skin of chalk having been stripped off violently from the chalk matrix, and with it the usual covering of the chalk as it occurs when *in situ* and undisturbed on the foreshore, that before it was moved this cake of mixed materials formed an integral part of the uppermost bed of the chalk with the Weybourne Crag attached, and that the detachment and portage of the whole mass took place after the deposition of the Weybourne or Norwich Crag.

I ought to add that this remarkable cake of conjoined chalk and crag is matched in the case of the longer and better known tabular chalk masses between East and West Runton Gap. On portions of two of these the same bed of hard pan or consolidated gravel occurs. In these cases the gravel is represented in the sections of the Survey Memoir lying on the chalk, but its significance is entirely overlooked, and, *mirabile dictu*, the gravel is labelled *glacial gravel*. What there is glacial about it defies conjecture. It is formed of small rounded flint pebbles with occasional quartzites, like all the other gravels of the upper crag, and, so far as I know, of nothing else, and is the exact equivalent of the hard pan as it exists similarly planted upon the chalk when the latter occurs with the crag in juxtaposition above

great stretches of the coast. It is, in fact, a definite proof that these chalk cakes, like the serpentinous mass of chalk last mentioned, were violently detached after the deposition of the Weybourne Crag.

I may say that these tabular chalk cakes, like the mixed mass above named, have meandering or arched outlines, and that the once horizontal beds of flints in them have been bent into the same curves, which imply the exercise of similar forces as those in the chalk still *in-situ* and were doubtless induced at the same time.

It would be a great mistake to suppose that these enormous masses of detached chalk lying in and surrounded by later beds are a peculiar feature of the cliff sections only. They also occur in several sections far inland, as far, in fact, as Leicestershire and Northamptonshire, in several places having actually been used as chalk-quarries. What is perfectly plain is that the phenomenon they witness to, is that of a violent and notable dynamical movement, however caused, and which is to be put alongside the other proofs of similar dislocation and violent breakage already mentioned in this paper.

We have no reason to suppose that the movements involved belonged to different periods and occurred at different times. On the contrary, such evidence as is available, as we shall see, goes to show that it took place at one time. We have seen that on the coast this is shown to have been after the deposition of the so-called Weybourne Crag, whose shells are found in the red pan. The fact of the Norwich Crag and the so-called Bure Valley Beds (which are merely the local representation of the Weybourne Crag) occurring so far from the coast and at such a comparatively high level, and the fact that the chalk beds in the former place correspond to those between Weybourne and Runton, as Mr. C. Reid says (see Memoir on Cromer, etc.), is strong testimony to the fact that the dislocations of various kinds here referred to, and so notorious to every student of the district, were contemporaneous and occurred at the same geological epoch, namely, after the deposition of the Norwich or Weybourne Crag.

This view is, to some extent at least, that of the Geological Surveyors. Thus, speaking of the bent and distorted chalk at Trimingham, Mr. C. Reid says: "That this contortion is of Pleistocene date is proved by the similar disturbances of the overlying beds, and by the intrusion of tongues of Boulder Clay into the Chalk. Lyell was fully aware of this unconformity and gave illustrations of it; he mentioned the mixture of Chalk and Boulder Clay on the foreshore, and considered that the contortion must clearly have been formed subsequently to the deposition of the Drift" (Geology of Cromer, etc., p. 95).

What Mr. Reid here says of the local disturbances at Trimingham I would apply to the Chalk dislocations of all North Norfolk and its borders, which I claim to have all been contemporaneous and posterior to the deposition of the Newer or Norwich Crag. To sum up the case as far as we have gone, the evidence of violent change and movement and dislocation in the Chalk of Norfolk after the deposition of the latest Crag beds is very widespread and very cumulative. It would appear further incontrovertible from the available facts that when these newer Crags were being deposited the contour of Norfolk

was quite different to what it is now, and that a considerable part of it was occupied by beds, not of curved and broken chalk as now, but of horizontally bedded chalk lying at the level of the laminarian zone upon which the Crag shells lived and the Newer Crag beds were deposited, and that it was after this time that the whole of it was subjected to violent forces which dislocated and broke it and gave it its present contour. These conclusions seem inevitable.

The next question that arises is what was the force or what were the forces which caused these dislocations and movements, and which occurred on this great scale not in remote geological time but, geologically speaking, only yesterday, at an epoch, in fact, when the possibility of such movements has been so continuously scouted by the champions of orthodox geology.

There are only two ways in which this widespread dislocation and destruction could take place. It must have been either by the application of force from the outside and from above, or by the exercise of subterranean energy. In regard to the former notion, which is the orthodox one, the difficulty is stupendous. We must not forget that the total thickness of the Chalk in this part of Norfolk must be very great, probably largely exceeding 500 feet, and further that chalk is a very tough material, offering great resistance to pressure. How we are to secure an instrument acting from above which could twist and curve this material into meandering curves, arching it here and depressing it into synclinal folds elsewhere, and could further break off with ragged edges and deeply wounded surfaces great angular masses and cakes of chalk, passes my comprehension. Yet the postulate has been gaily appealed to by most of the orthodox geologists without any attempt whatever being made to justify it.

The Rev. O. Fisher, who generally argues in a strictly inductive way, writing as far back as 1868, attributed phenomena such as we are discussing to the pressure exercised by large masses of material on the underlying beds. Thus he says *inter alia*: "in attributing contortions in the underlying beds to the deposition of masses of matter upon the surface, I would go to the extent of suggesting that the remarkable bluffs of chalk at Trimingham may have been upraised by some such action." Surely here we have a whole series of unverified premises! Where can we find a single instance of such contortions and breakage as we are discussing as the result of placing great weights on the surface of the earth? Take the Pyramids, or buildings like St. Paul's or St. Peter's, among human experiments, or turning to purely natural phenomena, take the innumerable examples we can find of perfectly horizontal beds lying under tremendous loads of superincumbent material much greater than any that can be appealed to as overlying the Chalk in Norfolk. Surely the idea is purely transcendental one. How, again, is the pressure of such a mass, even if effective for the purpose of producing dislocations, to cause meandering contours and alternate arches and hollows in chalk beds several hundred feet thick, or how is it to break off vast masses from their matrix with raw and angular edges? Assuredly, if the pressure is sufficiently great, crushing will ensue; that is true enough, but has anyone attempted to calculate the amount of mere pressure that would

be needed to crush the chalk, a problem which Mr. O. Fisher might easily have faced before offering an hypothesis so remote from probability. But even if he had faced it we should be no nearer. There is no sign whatever of mere crushing in these chalk cliffs and great chalk masses. The chalk in them and the lines of flint in them are quite intact, and so are the beds of consolidated gravel and finely laminated sand which in many places are adherent to them. We should expect if the pressure had been sufficiently great to be efficient at all that it would have crushed these chalk beds into powder, and not curved them and twisted them in this way, or broken them off with sharp edges. The whole process seems to me utterly fantastic and impossible. I am not alone in thinking so. In this instance I quite agree with Mr. C. Reid when he says: "The Rev. O. Fisher's theory of the forcing up of the beds by irregular deposition of masses of material on their surface seems inadequate to the formation of contortions on so vast a scale. It is doubtful whether anything less than a mountain piled on the surface at Trimingham would be sufficient for the contortion of 200 feet of underlying strata." This is quite judicious, although it understates the difficulty, but in the face of such a statement what are we to say of Mr. Reid's own theory? After thus demolishing the Rev. O. Fisher's notion that the chalk dislocations were due to the differential pressure of superincumbent masses of strata as quite inadequate, he proceeds, without any attempt at a physical analysis of the conditions of the problem, to apply the very same kind of explanation himself, only substituting ice for beds of rock or sand or clay. Assuredly, nothing can well be more inconsequent, for it merely adds to the difficulties instead of diminishing them. Let us analyze his argument. The distinction in Mr. C. Reid's mind seems in some way to rest on a notion that while the postulated superincumbent rocks, sands, or clays here referred to would be *ex hypothesi* stationary, ice is in a measure mobile, and he says the explanation of the broken and contorted condition of the chalk is only possible on the hypothesis of "a lateral thrust, or of a sliding pressure from above."

To be continued.

V.—Two New Species of *Eurypterus* from the Coal-Measures of Ilkeston, Derbyshire.

By Henry Woodward, LL.D., F.R.S., V.P.Z.S., F.G.S.

PLATE XIII.

BY the kindness of Mr. Henry A. Allen, F.G.S., of the Geological Survey of England, three examples of *Eurypterus*, in clay-ironstone nodules, showing impression and counterpart, together with a fragment of a fourth example, all from the Coal-measures to the north-west of Ilkeston, have been most obligingly lent me for description by their discoverer, Dr. L. Moysey, M.A., of St. Moritz, Ilkeston Road, Nottingham.

Remains of *Eurypterus* are extremely rare in the Coal-measures. The earliest Carboniferous *Eurypterus* discovered and described was

E. Scouleri of Hibbert,[1] from a quarry at Kirkton, near Bathgate, West Lothian, in a fresh-water limestone containing much silica and associated with fronds of *Sphenopteris Hibberti*.[2] The first to be described in America was *Eurypterus* (*Anthracoconectes*) *Mazonensis*, by Messrs. Meek & Worthen, from the Coal-measures of Grundy County, Illinois.[3] The next was in 1877, by Mr. Charles E. Hall, of the Geological Survey of Pennsylvania,[4] under the name of *E. Pennsylvanicus*, from the Lower Carboniferous rocks of Venango County, and another example from the Coal-measures of Cannelton, Pa., under the name of *Eurypterus* (*Dolichopterus*) *Mansfieldi*. These were noticed and refigured by Professor James Hall,[5] who added figures of Eurypteridæ from the Lower productive Coal-measures in Beaver Co. and the Lower Carboniferous Pithole Shale, Vernango Co. The additional species noticed by Professor James Hall, were *E. Beecheri*, Hall (an Upper Devonian form from Warren, Pa.); *E. potens*, Hall, Carboniferous, Pa.; *E. stylus*, Hall, shale below Cannel Coal, Darlington, Pa.

A very interesting and well-preserved *Eurypterus*, named *E. scabrosus*, was discovered in 1886 in the Lower Carboniferous Series of Eskdale, Scotland, and figured and described in 1887.[6] Part of the body of another example, named *E. Wilsoni*, from the Coal-measures of Radstock, Somerset, was also figured and described by the writer.[7]

Other remains of *Eurypterus* have been referred to *E. Scouleri*[8] from the Carboniferous of Cape Breton. Another species, not determined, was noticed by Salter from the Carboniferous of Nova Scotia. A form doubtfully referred to *E. Scouleri* from the Upper Devonian of Kiltorcan, Ireland, and one named by Salter *E. pulicaris*,[9] from the Devonian of St. John's, New Brunswick; one from the Lower Devonian of Arbroath, *E. Brewsteri*[10]; one from the Passage Beds, Purton, Herefordshire, named *E. Brodiei*. H. Woodward, complete the Carboniferous and Devonian series.

In the Upper Silurian no fewer than 17 species of *Eurypterus* have been described, 10 being from Russia and North America, and 7 from Ludlow, Kendal, and Lanarkshire; the most perfectly preserved, however, are from North America, and from the Island of Oesel in the Baltic.[11] The dermal coverings of some of these

[1] Trans. Roy. Soc. Edin., vol. xiii (1836), pt. 1, p. 280; pl. xii.

[2] H. Woodward: Mon. Pal. Soc. Merostomata, 1872, pp. 153, 180, pls. xxv–xxvii and text-figs.

[3] See Amer. Journ. Science, vol. xlvi (1868), p. 21; afterwards more fully illustrated and described by the same authors in the Reports Geol. Surv. Illinois, vol. iii (1868), p. 544.

[4] Proc. Amer. Phil. Soc., vol. vii (1877), p. 624.

[5] Second Geol. Surv. Pennsylvania: Report of Progress P.P.P., 1884.

[6] H. Woodward: Geol. Mag., 1887, pp. 481–484, Pl. XIII.

[7] Geol. Mag., 1888, pp. 419–421, Woodcut.

[8] J. W. Salter: Quart. Journ. Geol. Soc., vol. xv (1859), p. 232, pl. x.

[9] J. W. Salter: Quart. Journ. Geol. Soc., vol. xviii (1863), p. 316; vol. xix, pp. 78–79.

[10] H. Woodward: Geol. Mag., Vol. I (1864), p. 200, Pl. X, Fig. 3.

[11] Fr. Schmidt, "Die Crustaceentauna der Eurypteren-schichten von Rootzikill auf Oesel. Miscellanea silurica, iii": Mém. Acad. Imp. Sci. St. Petersbourg (VII), vol. xxxi, No. 5, 1883.

Swedish specimens have lately been obtained in so perfect a state of preservation that they have been mounted on glass by Professor E. J. G. Holm, and a series so prepared are preserved in the Natural History Museum, Cromwell Road.[1]

Eurypterus Moyseyi,[2] H. Woodw., sp. nov. (Pl. XIII, Figs. 1, 2.)

Figs. 1 and 2 on our Plate XIII are drawn, slightly enlarged in each case, from one of the sides of two irregularly-shaped clay-ironstone nodules, which have been split open; Fig. 1 displaying also upon its inner surface, not only the Arthropod about to be described, but also the pinnule of a Neuropterid fern, attesting the near presence of land-conditions, as seen also on pl. iv, fig. 3, pl. vi, and pl. viii, fig. 2, of Professor Hall's figures of Eurypterids from the Carboniferous beds of Pennsylvania already referred to.

Our Fig. 1 shows clearly the semicircular fronted head-shield, with its truncated posterior border followed by seven rather narrow but transversely broad and arching post-cephalic segments. The head-shield carries the eyes, which are prominent and placed anteriorly and subcentrally on its upper surface; they are smooth (not facetted) and of the usual reniform outline. A raised semicircular ridge seems to unite them in front, but this is probably due to the squeezing upwards of the bases of two of the anterior pairs of endognaths; a detached portion of one of the palpi (*en.*) is seen on the left side of the head-shield, and two others on the right side.

Owing to the circumstance that the posterior portion of the cephalic shield has adhered to the counterpart of the nodule, the mouth organs on its under-side are more clearly exposed to view, and we see the oval metastoma, or post-oral plate (*m.*), occupying the centre of the space, having its attached hinder border rather below the posterior margin of the head, while its anterior, slightly notched, free extremity reaches to the centre of the head-shield. The broad basal joints of a pair of powerful ectognaths (*ec.*, *ec.*) flank the metastoma on either side; only a part of one of their swimming palps (*ec.*) is seen lying detached on the left side; perhaps the appendage labelled (*en.* 6) on the right side may be the other palpus, the distal spatulate extremity being in that case broken off, or concealed by the matrix. Endognath 5 (*en.* 5, Fig. 1) is a slender organ having only four of its original seven joints visible; the terminal joint being a simple and sharp spine.

The narrow median organ, or central appendage, of the opercular plate, the extremity of which is rounded, is seen in Fig. 1, *ap.*, as a well-marked impression underlying the four anterior post-cephalic segments.

As in other species of this genus, the first segment following the head-shield is narrower than the rest; the three which follow are deeper, and increase gradually also in breadth; then follow three more, which become gradually narrower but do not diminish in

[1] E. J. G. Holm, "Ueber die Organisation des *Eurypterus Fischeri* Eichw.": Mém. Acad. Imp. Sci. St. Petersbourg, Phys.-Math. Cl. (VIII), vol. viii, No. 2, 80 pp., 10 pls., 1898.

[2] Named in honour of the discoverer, Dr. L. Moysey, M.A., of St. Moritz, Ilkeston Road, Nottingham.

depth. These seven segments forming the thorax (*pereion* of Spence Bate) give to the body a somewhat globular or rounded contour. Those which follow (probably seven in number) were greatly reduced in breadth, but increased somewhat in depth, ending in all probability in a more or less long slender ensiform telson. Figs. 1 and 2 have only eight and nine segments respectively preserved, the remainder of the abdominal series, which extended into the matrix beyond the edge of the clay-ironstone nodule, being lost.

In *Eurypterus*, as in so many other Arthropods, each somite is clothed in a chitinous or calcareo-chitinous envelope, an upper part (or *tergum*) and a lower part (or *sternum*) giving rise at their junction to small recurved epimeral plates or pleurae on the lateral margins of each segment. These tergites and sternites, in fossilisation, have been pressed together, and are often somewhat displaced along the margins of the segments, but the outer upper surface can always be readily detected by the presence of rows of minute squamate markings so characteristic of all the Merostomata (see Figs. 1 and 2).

Although the head-shield in Fig. 2 is less well preserved than that of Fig. 1, and the eyes are very indistinct, there are portions, nearly in place, of at least four jointed endognaths or palpiform organs (*en.* 1, 2, 3, 4), which served as mouth organs and also as locomotory appendages, the last and most posterior pair, which are always the largest, being modified to serve as powerful swimming feet. Probably *en.* 3 and 4 may represent this pair of swimming feet, one of which has been in that case displaced from the right side. The basal joints of this posterior pair occupy in Fig. 2 the same position as in Fig. 1, being placed one on either side of the oval metastoma. The greater part of the opercular plate (*op.*), situate immediately behind the head, is exposed to view by the removal of the tergites of the first and second body-segments, leaving the left side and the central appendage uncovered. Two of the series of narrow abdominal segments following the broad thorax are preserved in Fig. 2; also the pointed recurved pleurae or epimera on the right side of the seven thoracic plates, which are well shown and quite in order.

In the figures given by Professor James Hall of the American *Eurypterus Mansfieldi* from below the Cannel Coal, Cannelton, Pa., the epimeral pieces on the margins of the body-segments are shown to be produced into strongly recurved spinous processes (see particularly op. cit., pl. iv, fig. 3, and pl. v, figs. 3 and 11). These spinous lateral processes also frequently occur detached, and I have seen such from our own Coal-measures, but I do not think they were so prominent on the segments of *Eurypterus Mayseyi*.

Measurements.—Fig. 1. Length of head-shield 21 cm., breadth at base 26 cm.; breadth between eyes at back 10 cm., length of eye 4 cm.; length of metastoma 10 cm., breadth 8 cm.; length of median appendage to opercular plate 12 cm., breadth 4 cm.; length from base of metastoma to base of 7th segment 21 cm.; greatest breadth of thorax 29 cm., average depth of thoracic segments 5½ cm.; breadth of first abdominal segment 15 cm., depth 7 cm.

Fig. 2. Length of head-shield 17 cm., breadth of base 23 cm.; length of seven thoracic segments 25 cm., greatest breadth 26 cm.; length of

median appendage to operculum 8 cm., breadth 4 cm.; breadth of 1st abdominal segment 14 cm., length 7 cm.; metastoma: length 10 cm., breadth 7 cm.

In the specimens of *Eurypterus*, figured and described by Professor James Hall from Pennsylvania, the body-segments, especially those of the abdomen, appear to be more narrow and elongated than these Derbyshire specimens indicate. *E. Mayseyi*, for instance, has a more globular or rotund thorax, and the ornamentation is less spinose and the squamæ are more minute.

The thoracic segments figured by me (see Geol. Mag., 1888, pp. 419–421) from the Coal-measures of Radstock, Somerset, evidently belonged (like the Scottish specimen named *E. scabrosus*) to a much larger form, at least twice, if not thrice, as large.

Eurypterus Derbiensis, sp. nov. (Pl. XIII, Fig. 3.)

This specimen is much smaller than the preceding examples and not very clearly preserved, being mixed with numerous detached and broken leaves of a fern; nevertheless, although at first doubtful, I am now inclined to regard it as being certainly distinct from *E. Mayseyi*, with which it was found associated.

The head-shield has the usual subquadrate form, rounded in front; the eyes, which are prominent and a little larger in proportion to its relative size, are placed somewhat closer together, and rather nearer the anterior margin than in *E. Mayseyi*. Two imperfect endognaths (*en.*) are seen on the right side of the head, and one of the swimming feet (*ee.*) on the left side. The metastoma or post-oral plate (*m.*) is oval in form, its posterior border being hidden beneath the thoracic segments, which are squeezed together somewhat and have lost a part of their margins. There is a faint impression on the counterpart (not drawn) of a long median appendage belonging to the opercular plate seen beneath the thoracic sternites. What is very interesting is the presence of about six narrow but deep abdominal segments, having a crenulated ornamentation suggesting the presence of a row of marginal spines along the posterior border of each tergite. Similar plicæ are represented by James Hall in *E. Mansfieldi* (op. cit., pl. iv, fig. 3; pl. v, fig. 3; and pl. vi from Pennsylvania.

Dimensions.—Total length of specimen 30 centimetres, greatest breadth of thorax 12 cm.; breadth of head 10 cm., length of head 6 cm.; length of thorax 9 cm.; length of abdomen 15 cm.; breadth of anterior segment 8 cm., length 4 cm.

This specimen (Fig. 3) differs slightly in the form of the head-shield, which is rather more quadrate than in Figs. 1 and 2; the body is more slender, and the plicæ (or spines?) along the posterior border of the abdominal segments are not seen on the posterior somites of Figs. 1 and 2. Possibly this might be considered as the male of the larger species, but the only other evidence is in the form of the imperfectly indicated median appendage of the opercular plate. Against this, however, is the fact that Figs. 1 and 2 differ probably quite as much from each other in the form of the opercular plate, and therefore Fig. 1 might equally well be deemed to be the male and Fig. 2 the female of the same species.

Under these circumstances, in order to avoid the inconvenience and suspense occasioned by a nameless fossil, I would suggest for Fig. 3 the specific designation of *Derbiensis* as serving also to mark geographical locality of this individual.

All the specimens are in the possession of the discoverer, Dr. L. Moysey, M.A., St. Moritz, Ilkeston Road, Nottingham, to whose courtesy I am indebted for permission to describe these very interesting Arthropods.

EXPLANATION OF PLATE XIII.

Figs. 1 and 2.—*Eurypterus Moiseyi*, H. Woodward, sp. nov. Enlarged 1½ times nat. size.

Fig. 3.—*Eurypterus Derbiensis*, H. Woodward, sp. nov. Enlarged 2½ times nat. size.

Clay-ironstone Coal-measures, all from a few feet below the "Top-Hard-Coal," 1½ miles N.N.W. of Ilkeston, Derbyshire. Collection of Dr. L. Moysey, M.A.

en. endognath, one of the series of mouth organs (serving as maxillipeds) in Fig. 2 I have indicated *en.* 1, 2, 3, and 4.

ec. ectognath, indicate the basal joints (coxa) which form the chief organs of manducation; they form also powerful swimming organs (see figures in Professor Hall's work and in H. Woodward's Monograph on the Merostomata).

m. metastoma or post-oral plate, usually cordiform.

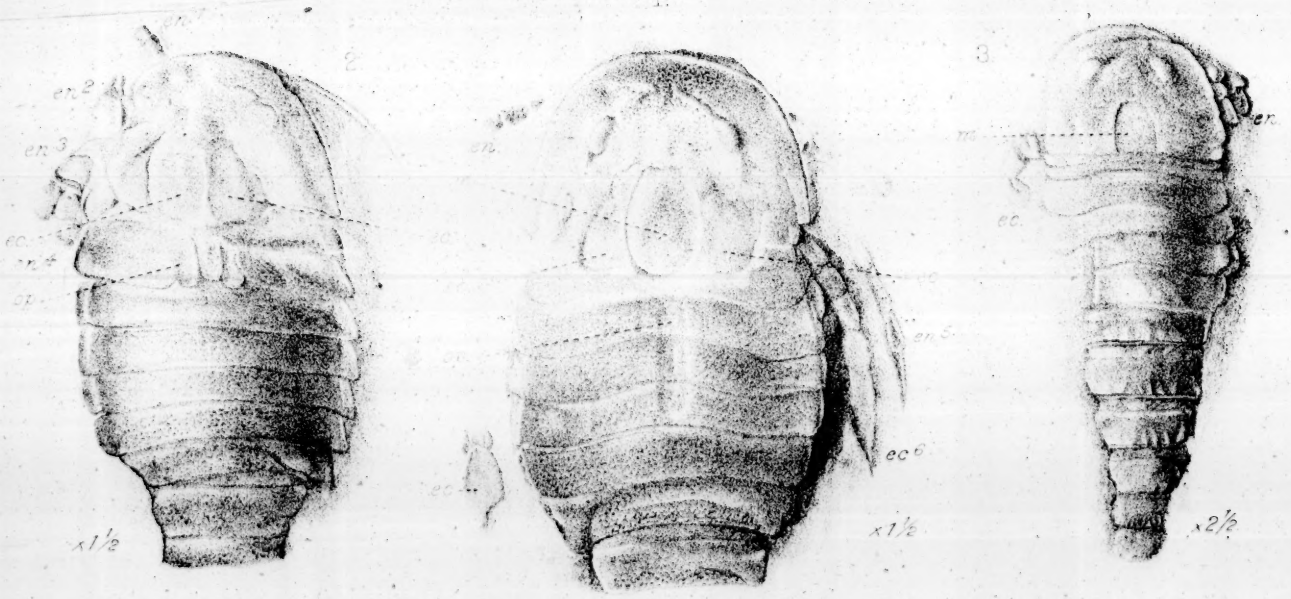
REVIEWS.

I.—The Zones of Neolithic Times.

Strandlinjens Beliggenhed under Stenalderen i det Sydöstlige Norge. By W. C. Brögger. With a German resumé, 11 plates, 2 maps, and 9 figures in the text. Norges Geologiske Undersögelse, No. 41. Kristiania, I commission hos H. Aschehoug & Co.; A. W. Bröggers Bogtrykkeri; 1905.

WE live in an age of zoning, but one may be pardoned for feeling surprise when one reads of the zoning of Neolithic deposits. The period embraced is geologically so short that one might on first thoughts have considered its subdivision into well-characterised zones as almost impossible. Yet this is what Professor Brögger has done, and it is of this that he gives us an account in the present volume. He has taken advantage of the rapid development of the skill and industry of man at this time, and has selected as his zone fossils the axe-heads of stone and flint which are found in the deposits of this age. He classifies them in certain types, according to their peculiarities of form, and each type he shows to be associated with a strand-line formed at some stage of recovery from the Littorina-Tapes depression. He is aided in this by the fact that the inhabitants of Norway during the early portion of the Northern Stone Age were fisher-folk, and lived mainly on the sea-shore. During its later stages they became more and more an agricultural and pastoral people, and their dwelling-places being no longer confined to the shore do not afford so exact a determination of its level. Yet even in this case it is possible to fix a limit for the height of the sea at that time.

A general account is given of the Littorina-Tapes depression and of



J.M. Woodward del. et lith.

West, Newman imp.

Figs 1 & 2 Eurypterus Moyseyi, *H Woodw.*, Fig 3 Eurypterus, *sp.*
Coal-Measures, Ilkeston, Derbyshire

the strand-lines formed during recovery from it. The dwelling-places and other finds of stone axes are then described and classified, and the various types shown to correspond to the different shore-lines. An idea of the nature of the results obtained may be gathered from the following brief summary, giving the height in metres of the strand-lines at Kristiania which correspond to the several archæological stages:—

End of Older Stone Age (rough-hewn axes of 'Nöstvet' type), sea at 70 m.

End of Middle Stone Age (stump-necked round axe), sea at 55 m.

End of older part of Younger Stone Age (thin-necked axe), sea at 25 m.

End of Youngest Stone Age (thin-necked axe and shaft-hole axe), sea at 15 m.

End of Bronze Age, sea at present level.

The end of the Older Stone Age, or Nöstvet-time, corresponds with the maximum of the Littorina-Tapes depression. By comparison with the amount of elevation which took place during the Bronze Age and Younger Stone Age, the absolute durations of which have been estimated by archæologists in centuries, it has been found possible to make an estimate (admittedly uncertain) of the time of the Littorina-Tapes Maximum, the date arrived at being about 5000 B.C.

One cannot give this delightful book higher praise than to say that it is just such a work as we have learned to expect from the hand of Professor Brögger. It will be found essential to all, whether geologists or archæologists, who are interested in the history of post-Glacial time.

W. B. W.

II.—New Maps of the Geological Survey of Scotland.

THE Survey has recently issued two sheets of the Geological Index Map of Scotland, scale 4 miles to 1 inch (= $\frac{1}{253,440}$), viz.: Sheet 16 (size 21 by 13½ inches measured over the topographical work), colour-printed, 1907, price 2*s.* 6*d.*, and Sheet 17 (size 17 by 13½ inches), colour-printed, 1907, price 2*s.* 6*d.*

Sheet 16 includes Wigtonshire, Kirkcudbrightshire, part of Ayrshire, the south of Arran, and the south of Kintyre. In ascending order the rocks shown are Metamorphic Rocks (in Kintyre), comprising Green Beds, Limestone and Undifferentiated Schists; Lower Silurian (Arenig, Llandeilo-Caradoc); Upper Silurian (Llandovery-Tarannon, Wenlock-Ludlow); Old Red Sandstone (Lower, Upper); Carboniferous (Calciferous Sandstone, Carboniferous Limestone Series, Moor Rock, Millstone Grit, Coal-measures); Trias (Sandstones, Marls); Recent (Marine and Fresh-water Alluvium, Peat, Blown Sand). The igneous rocks are Volcanic Rocks, Intrusive Massive, including Granite,[1] Felsite, Porphyrite, Andesite, Diorite and Hyperite), Basalt and Dolerite in dykes and in sheets, Gabbro,[1] Serpentine and Peridotite,[1] Fragmental, Agglomerate in necks, Extrusive Andesitic Lavas, Basaltic Lavas, Tuffs.

[1] Usually considered to be plutonic.

Sheet 17 (next sheet to east of Sheet 16) includes part of Kirkcudbrightshire, Dumfriesshire, Roxburghshire (the eastern half of the town of Dumfries). More than half of the area of the map is blank as representing part of England. This is a pity. The good example set in Sir A. Geikie's Map of England and Wales and in the maps of Stieler's Hand Atlas of giving full detail of all the country within the sheet should have been followed. The rocks represented are Lower Silurian (Arenig, Llandeilo-Caradoc); Upper Silurian (Llandovery-Tarannon, Wenlock-Ludlow); Old Red Sandstone (Lower, Upper); Carboniferous (Calciferous Sandstone, Moor Rock, Coal-measures); Trias; Recent (Marine and Fresh-water Alluvium, Peat); Volcanic Rocks (Intrusive Massive, Granite-Felsite, Porphyrite, Andesite, Basalt and Dolerite in dykes and in sheets (Intrusive Fragmental, Agglomerate in necks (Extrusive), Andesitic Lavas, Basaltic Lavas, Tuffs.

Compared with Sir A. Geikie's, 10 miles to 1 inch, Geological Map of Scotland, the amount of detail shown on these sheets with 6¼ times the space is not as great as might have been expected.

B. Horson.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

April 17th, 1907.—Sir Archibald Geikie, D.C.L., Sc.D., Sec.R.S., President, in the Chair.

Proposed Election of Women Associates of the Geological Society of London.—The President announced that a Special General Meeting would be held on Wednesday, May 15th, 1907, at 7.30 p.m., for the purpose of considering and voting on a proposed new section, and alterations in existing sections, of the Byelaws.[1]

The following communications were read:—

1. "The Toadstones of Derbyshire, their Field Relations and Petrography." By Henry Howe Arnold-Bemrose, J.P., M.A., F.G.S.

The district over which the Toadstones are seen may be divided into three main areas of volcanic activity, between which there are no exposures of igneous rock.

I. The North-Western or Miller's Dale Area.
II. The South-Eastern or Matlock Area.
III. The South-Western or Tissington Area.

In each of these areas there are lava-flows, bedded tuffs, and volcanic vents, and in the Miller's Dale and Matlock areas several intrusive sills. In the Miller's Dale and Matlock areas the igneous rocks are, with the exception of the Hopton vent, entirely in the Mountain

[1] May 15th, 1907. At the Special General Meeting held on this day the proposed new Byelaws for the Election of Women Associates were submitted to the Fellows, and after an animated discussion the proposition was put to the vote and lost, 32 Fellows voting for and 31 against the motion.

Limestone; but in the third area they are mostly in the Yoredale Shales, and lava plays only a subordinate part. In the Miller's Dale area the upper lava is the thicker, and extends over a greater district than the lower, while in the Matlock area the converse is true. In the former area the lavas are separated by about 150 feet of limestone, in the latter by about 80 to 100 feet. The upper lava of Miller's Dale is on a lower horizon than the lower lava of Matlock, and the limestone above it contains at least two bands of interbedded tuff. The lavas are vesicular and amygdaloidal in structure, and often very much decomposed. They contain olivine, augite, and felspars, magnetite and iron-oxide; the felspars are often present in two generations. The sills are, for the most part, ophitic olivine dolerites, and pass from a very coarse-grained dolerite through the intervening stages into a fine-grained dolerite or basalt; they are similar in structure to certain Tertiary dolerites. The following vents are described:—In the north-western area, those at Speedwell, Monks Dale, and Calton Hill; in the south-east, at Cracknowl, the Grange Mill vents, Ember Lane, Moor Lane, and the Hopton vent; in the south-west, Kniveton Wood Cottage, Woodeaves, and Wibben Hill. The majority of the vents are composed of volcanic agglomerate; but the Calton vent, near Miller's Dale, is a typical basalt with a small portion of agglomerate, and the Hopton vent is a breccia of basalt fragments. The Toadstones have all been mapped on the 6-inch scale, and petrological accounts of the different rocks are furnished.

2. "Data bearing on the Age of Niagara Falls." By Professor Joseph William Winthrop Spencer, A.M., Ph.D., F.G.S.

The author has been engaged in investigations for a monograph on Niagara Falls, to be published by the Geological Survey of Canada. Soundings at all the points of great changes in the Gorge have been successfully undertaken, borings were put down for the exploration of buried valleys, and instrumental surveys made of the original river banks and the physics of the stream. The mean recession of the crest line of the Falls is found to be 4·2 feet a year under existing conditions, and this rate has approximately obtained for 227 years. But this rate will not give the age of the Falls, on account of former great variations in the volume of the river and in the height of the Falls themselves. The chief change in volume of water depends on the fact that originally Lake Erie alone was discharged over the Falls, when the supply of water was only 15 per cent. of the present discharge. Lake Ontario, too, stood at a higher level, and thus the cutting back from Queenstown to Foster's Flats was effected with a small water discharge and, at first, a low head. After an uplift which raised the crest of the fall considerably above Lake Ontario, a slight depression followed which "drowned" part of the lower gorge. This cutting is calculated to have taken 35,500 years for a distance of 14,400 feet. Above Foster's Flats the sudden widening indicates the inflow of the other lakes into Erie, greater water discharge, and greatly increased rapidity of recession. The changes in height of the Falls and resistance of the rocks are examined in detail, and the small influence of pre-Glacial filled channels estimated. The Whirlpool is on the site where the recession broke down the partition separating

the head of the Whirlpool—St. David's buried gorge, and began to empty out the contents of this valley. The cutting with the full power of the water of the four lakes varied at times according to the height of the fall, and is calculated to have occupied only 3,500 years, for the cutting back of about 4 miles above the head of Foster's Flats. Thus the entire age of the Falls is given as 39,000 years.

II.—Mineralogical Society.

Tuesday, March 19th.—Professor H. A. Miers, F.R.S., President, in the Chair.

On the silver deposit or Sedgman lode in the Perran Mine, Cornwall, by F. H. Butler. The lode runs through killas in an approximately north and south direction. The silver ore, consisting almost solely of cerargyrite, occurs in compact masses, or finely disseminated in a gossany limonite. Splintery and ferruginous quartz, the "cube course," is always a well-developed feature in the richest parts of the lode. The distribution of the cerargyrite, to the depth of 18 fathoms to which the mine has been worked, is roughly in accordance with the surface contour of the land; but segregations have also taken place along a series of lines running from above downwards. The source of the chlorine, the author suggests, might be sea-water that has reached abyssal regions.—On the minerals of the Silvermines District, Co. Tipperary, by A. Russell. The mines extend along an east and west line of fault in which Silurian, Old Red Sandstone, and Carboniferous rocks are brought into juxtaposition. Along its course in certain places mineralisation has taken place resulting in contact lodes and metasomatic deposits. In the Ballygowan South mine is an interesting occurrence of hemimorphite, the only one of the kind known in the United Kingdom. The mineral is found in brilliant crystals lining cavities in limonite. The gossan also contains irregular masses of argentiferous galena partially altered to cerrusite. At the Ballynoe mine copper pyrites, galena, and barytes form a lode between walls of Silurian and Carboniferous Limestone. At the Gortnadyne mine argentiferous tetrahedrite is found with copper pyrites and cerrusite ("cat-tooth ore"). An extensive series of old open workings of galena can be seen at the Shallee East mine.—On Baddeleyite from Ceylon, by G. S. Blake and G. F. Herbert Smith. Three brilliant crystals of the mineral were picked out from a number of specimens of the heavy minerals from the gem-districts of Ceylon which were sent to the Imperial Institute in 1905. Of the three crystals, one possessing only the prism zone was used for analysis, and found to contain nearly 99 per cent. of zirconia. On the two other crystals, one of which was a twin, were observed eleven forms, including one new one (210).—Zinciferous Tennantite from the Binnenthal, by R. H. Solly and G. T. Prior. Crystals of tennantite, one of which was a large cube, with faces deeply striated parallel to small tetrahedral faces, were found on analysis to contain nearly 8 per cent. of zinc.—On Strüverite, a new mineral by F. Zambonini and G. T. Prior. This new mineral was found in detrital masses of pegmatite

near Cravoggia in North Piedmont. Crystallographically it is very similar to rutile and tapiolite with axial ratio $a : c = 0{\cdot}6456$. Some of the crystals are elongated along the pyramid edge and are probably twins similar to those of ilmenorutile. The mineral is black and opaque, and has a specific gravity of 5·59. It contains titanic acid, zirconia, oxide of iron, and niobic and tantalic acid. The result of analyses suggests the formula $3\,FeO\,(Ta\,Nb)_2O_5\,.\,4\,ZrO_2\,.\,9\,TiO_2$, which may be written as a mixture of the three molecules $Fe(Ta\,Nb)_2O_6$, $Fe\,ZrO_2O_6$, and $Ti\,Ti_2O_6$ in the proportion of 1 : 2 : 3. Chemically it is very similar to ilmenorutile, but contains about 28 per cent. of ZrO_2, replacing part of the TiO_2.

CORRESPONDENCE.

PROFESSOR C. D. WALCOTT, LL.D., For. Mem. Geol. Soc.

Sir,—At the annual meeting of the Board of Regents of the Smithsonian Institution, held on January 23rd, 1907, Charles Doolittle Walcott, LL.D., was duly elected Secretary of the Smithsonian Institution, to succeed the late Samuel Pierpont Langley.

Melville W. Fuller.
Chancellor of the Smithsonian Institution.

Smithsonian Institution, Washington.

MRS. AYRTON'S THEORY OF RIPPLE-MARK.

Sir,—I am grateful to Mrs. Ayrton for having replied to my note of despair in the Magazine for February last. Our sole object is the truth in a question of small account with physicists, but of great importance to geologists. Owing to the action of the Royal Society and of the British Association in having Mrs. Ayrton's new theory presented to the scientific public in a demonstration at a conversazione, in a lecture to a section, and in a very short abstract in the Proc. Roy. Soc., there is next to nothing on public record, as even Mrs. Ayrton's abstract of her British Association lecture was not published in the Report, so there is little to discuss.

In her letter Mrs. Ayrton writes: "I actually showed at the lecture a series of periodically oscillating waves moving in one direction over a fixed bottom, and expending themselves on a sandy shore, and proved that under such waves ripples formed exactly as they did *in the moving tank* with vertical sides."

Mrs. Ayrton's own description of this experiment is as follows:—"I can imitate exactly the sand ripples *on the sea-shore* with water running in one direction only, if I slope the sand so that the water runs up it, as it does on the sea-shore, and if by means of a paddle I send a series of waves along the water in the direction in which it is running, if, in fact, I imitate the incoming tide." (Abstract, p. 3. Italics are mine throughout.

It is most important to note that, as stated, the ripples thus made are like those made on the shore, but they are dissimilar from those